A DELPHI STUDY USING VALUE-FOCUSED THINKING FOR UNITED STATES AIR FORCE MISSION DEPENDENCY INDEX VALUES

THESIS

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Abstract

Recently, the Air Force Civil Engineer Center (AFCEC) identified that the Mission Dependency Index (MDI) had issues with reflecting the criticality of some mission sets. The MDI is a constructed value assigned to assets that reflects the consequence of failure. The primary mission sets having MDI issues were non-flightline assets. The current Air Force MDI metric relies on data collected using the Naval Facilities Engineering Command (NAVFAC) methodology and adapts the data by using facility categorization codes. The result is a method that compares alternatives to each other to develop an individual asset's MDI value. As a corrective measure to this methodology, non-flightline centric mission sets have been allowed to adjust (i.e. increase) their asset MDI values. This modification in MDI values has led to inflation of the metric.

To address the issue, this research focuses on how the MDI values should be assigned by examining both public and private methodologies. Leveraging the Delphi technique and Value Focused Thinking (VFT), three models are created to suggest the proper inputs that should be considered when producing the MDI values for the Air Force's assets. The models inputs were interruptability, redundancy, replaceability and the number of missions affected. The Delphi panel weighted each input, and the resulting VFT models displayed the mirco (local-level) perspective, macro (headquarters-level) perspective, and the combined perspective.

To my beautiful wife

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I would like to thank my classmates for the good memories and friendships that we have created in the last 18 months. I look forward to serving with you throughout our careers.

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Matthew J. Nichols

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I. Introduction

Determining how to prioritize funding actions is a challenge for any corporation. The process of prioritizing projects is no different for Air Force Civil Engineers. The Air Force is responsible for an infrastructure portfolio of 139,556 assets worth $263.43 billion (Sitzabee & Harnly, 2013). Placing the value of these assets in perspective, the gross domestic product of the country of Finland in 2013 was $259 billion (CIA, 2014). The number of assets the Air Force is responsible for is around three times the amount the Target Corporation is responsible for and is comprised of 615 million square feet of building space (Byers, 2012). To demonstrate the magnitude of building space, the office space on Manhattan is 520 million square feet (Rudder Property Group, 2015).

Properly maintaining this large asset portfolio is a challenge for the Civil Engineer career field. This challenge is a result of applying funding to prioritized infrastructure maintenance and repair projects, and the interdependencies that occur from supporting the various mission sets in the enterprise portfolio. Fiscally, in order to support the portfolio, “the Air Force allocates $2.5 billion annually to maintenance and repair projects” (Sitzabee & Harnly, 2013:56), which equates to almost 1 percent of the overall portfoilio value each year. “An appropriate budget allocation for routine M&R for substanstail inventory of facilities will typically be in the range of 2 to 4 percent” (National Academy Press, 1990:xii). With the Air Force only receiving a fraction of the suggested funding to maintain a large real property portfolio, each funding decision must be made to maximize the cost efficiency.

The Air Force's facilities are interdependent to maximize efficiency to support various missions. Rinaldi et al.(2001), demonstrated that evaluating all of the interdependencies of infrastructure can be difficult, as shown by Figure 1. With all of the various dimensions of independencies, it is difficult to take into account every dimension in the prioritization of funds.

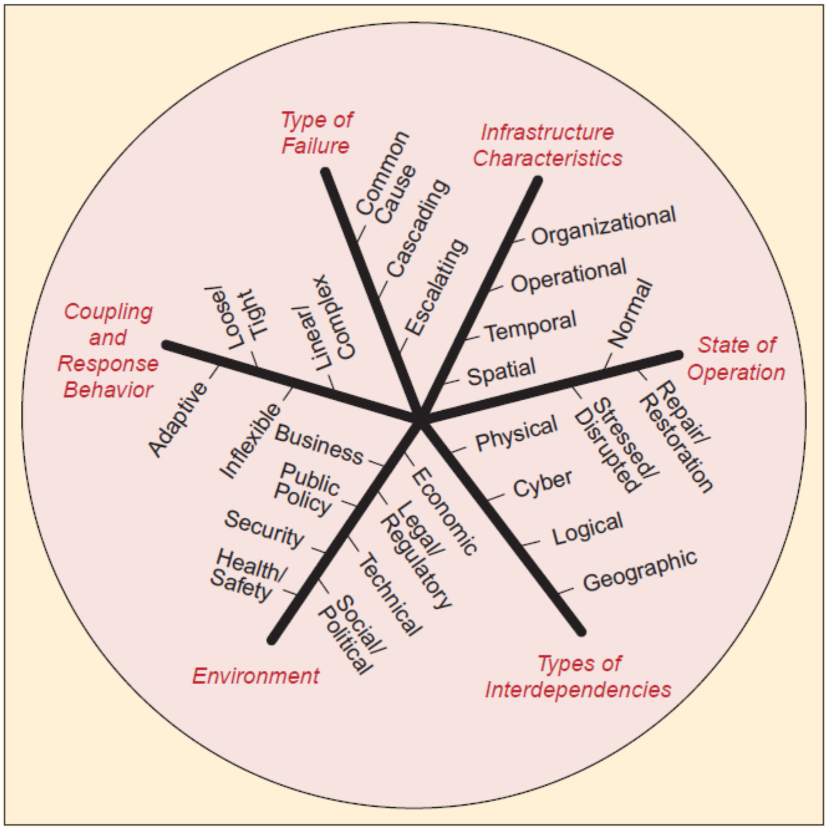


Figure 1. Dimensions of Infrastructure Interdependencies (Rinaldi et al., 2001)

In recent years, there have been three prioritization models applied to the Air Force infrastructure portfolio. The goal of these models was to decide where to best allocate the funds and to take into account many of the dimensions of infrastructure interdependencies. The two most recent models employed the mission dependency index (MDI) as an input. "Mission

Dependency Index is the value an asset brings to the performance of the mission as determined by the governing agency" (Federal Real Property Council, 2011:12). The MDI is a government term for an Asset Prioritization Index (API). Like MDI, an API measures the consequence of failure associated with a single building or asset. This research examines the MDI metric and suggests areas for improvement. Chapter I provides a brief background of the MDI, the problem statement, the research objective, investigative questions, the research approach, assumptions, and limitations of this research effort, and concludes with an overview of the remaining chapters.

Mission Dependency Index Background

Executive Order (EO) 13327, Federal Real Property Asset Management, was published in 2004 in an effort to mandate a more efficient way to manage federal real property assets through the implementation of asset management. Specifically, E.O. 13327 charges federal agencies to create "life-cycle cost estimations associated with the agency's prioritized actions" (Executive Order 13327, 2004:5898). Prior to the MDI, the Air Force implemented the Facility Investment Metric (FIM). The FIM model split all assets into facility classes based on the category code (CATCODE) of the individual asset. Eleven different types of facility classes existed ranging from operations and training to community support to delineate the mission set an asset supported. After determining the appropriate facility class, the user would be required to rank the facility's criticality. Air Force Instruction (AFI) 32-1032, Planning and Programming Appropriated Funded Maintenance, Repair, and Construction Projects (2003), defined the impact ratings to address how the failure of the facility would result in the failure of a mission. The three impact ratings were defined as critical, degraded, and essential to reflect the mission effect of an asset failing. To place a project in an impact category, it must have met the requirements outlined in AFI 32-1032. After bases and Major Commands (MAJCOMs) submitted the requirements to Headquarters Air Force (HAF), the HAF staff consolidated the requirements. After consolidation, HAF validated each requirement was placed in the proper facility class and impact rating category. Following the validation, the projects were prioritized for funding. This process met the desired effect of the executive order; however, the timeline and person-hours associated with this methodology did not allow for quick prioritization of assets. Figure 2 from AFI 32-1032 (2003) shows the FIM requirements matrix.

	IMPACT RATINGS		
Facility Class	**Critical**	**Degraded**	**Essential**
Operations and Training			
Mobility			
Maintenance and Production			
RDT&E			
Supply			
Medical			
Administrative			
Community Support			
MFH			
Dormitories			
Utilities and Ground Improvements			

Figure 2. FIM Requirements Matrix (AFI 32-1032, 2003)

In 2008, the Air Force Civil Engineer (CE) career field identified the need to create a system where all Air Force assets can be prioritized using a common metric. The common metric was intended to allow for a more transparent and effective funding model as part of the new system. One of the models the Air Force considered but did not adopt included the risk management methodology that combined the probability and severity of an asset's failure. The two metrics applied to the suggested model were the facility condition index (FCI) and MDI. These two new metrics allowed leadership to compare assets portfolio wide in a standardized fashion. Madaus (2008) created Figure 3 to help display these categories to the decision-makers to aid in the selection of the best course of action (COA).

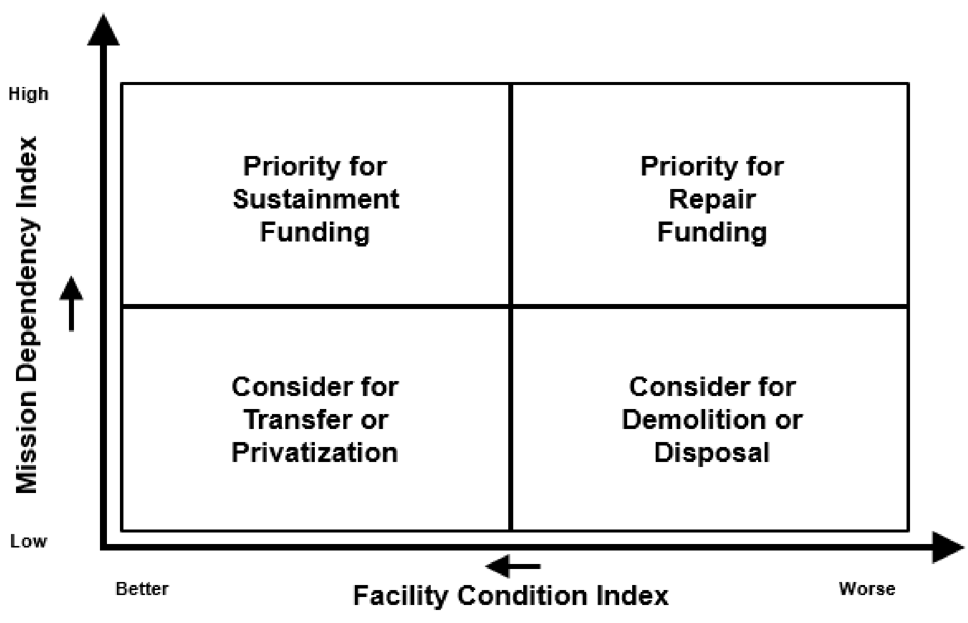


Figure 3. MDI vs. FCI Decision Matrix (Madaus, 2008)

The other model was a balanced scorecard that incorporated many of the strategic goals of the CE career field. The categories on the scorecard addressed health and safety compliance, the facility condition, MDI, local mission impact, cost efficiency, and the MAJCOM priority. Each category received a weight to contribute to the overall score. Once the overall score was calculated for each requirement, all projects were prioritized and the infrastructure funding was distributed accordingly. As shown in Figure 4, the balanced scorecard model could address multiple corporate goals; therefore, it was selected and implemented through 2013 (Headquarters Air Force, 2010).

	Wt %	Service Area	Significant 100	Very High 80	High 60	Moderate 40	Small 20	Not Rated 0
Technical Score	15%	**Health, Safety & Compliance*** *Two issues from same category bump a project up to the next risk category (e.g. "high" to "very high")	- RAC 1 - FSDC 1	-QD Arc violation -Nuclear Surety Deviation - Comply w/ fed/state law or regulation	- RAC 2 - FSDC 2 - Airfield Waiver - AT/FP, perimeter defense bldgs		- RAC 3 - FSDC 3 -Comply w/ UFC/DODI/AFI	No Health, Safety & Compliance Issues
		Asset Preservation, Development						
	10%	**Facility Condition (Q-Rating)**	<60 (Q4)	60-79 (Q3)		80-89 (Q2)		>90 (Q1)
	15%	**Mission Dependency Index**	ACTUAL MDI SCORE					N/A
	20%	**Local Mission Impact**	- Significant loss of msn capability & frequent msn interruptions		- Limited loss of msn capability & limited msn interruptions			- Marginal /no adverse impact to msn capability
	15%	**Cost Efficiency***						
		Energy Payback (PB)	PB ≤ 2 yrs		2yr < PB ≤ 5yr		5yr < PB ≤ 10yr	PB > 10yr
		Consolidation/Demo	< $20/SF		$20/SF-$40/SF		$40/SF-$60/SF	> $60/SF
		Companion Project	> $5M	$4M - $5M	$3M - $4M	$2M - $3M	< $2M	No Companion
Priority Score	25%	**Service Quality -- Reliability, Responsiveness & Capacity, Asset Management** (MAJCOM Priority)	Priorities: Each MAJCOM is allocated priorities in the following manor [(One per $1B of RECAP Plant Replacement Value + # of Major Installations) x 2]+3. Example: $21.4 B PRV & 8 bases = 2x(21.5 + 8)+3 = 62 earned priorities for scoring. Points for allocated priorities will be evenly distributed 0-100 across the total number of scored priorities for each MAJCOM.					

Figure 4. The Infrastructure Prioritization Balanced Scorecard (Headquarters Air Force, 2010)

When the balanced scorecard method was implemented, it used MDI as one of the inputs. The Air Force had to create a methodology to produce an interim MDI for facilities to use in prioritization method. The interim method relied on MDI values produced from the Naval Facilities Engineering Command (NAVFAC) model and assigned each identified MDI to each respective CATCODE. The data set was assigned by CATCODE similar to the National Park Service (NPS) methodology. The NPS methodology assigns the MDI values based on the CATCODE rather than individual assets; the NPS uses this approach because it does not require the same amount of data collection as the NAVFAC model. The team producing the interim MDI merged the two methodologies because there was "no clear Industry or OSD standard method to calculate MDI" (Madaus, 2008:6). This method was implemented with the intent to revisit the methodology and create a more accurate and repeatable metric.

After publishing the new MDI values for CATCODEs, the MAJCOMs identified numerous MDI-to-CATCODE mismatches that were not fulfilling the intent of measuring criticality and replaceability. MAJCOMs having a primary mission other than flight operations had the largest issue with the method. For example, Air Education and Training Command's (AETC) mission is to "Recruit, train and educate Airmen to deliver airpower for America" (AETC, 2014:1). Because of AETC's educational focus, their mission critical facilities are classrooms, dormitories, and training facilities. As a result, each MAJCOM could submit recommended adjustments to a specific CATCODE's MDI value. Initially, when an adjustment occurred to bring an MDI value up, the overall distribution of the CATCODEs was renormalized to maintain HAF's desired normal distribution and their desired range of values from 1-100. Over time, that corrective action no longer occurred. As each justification was approved, the MDI distribution shifted, becoming left skewed, and compacting the effective range to 32-99.

Problem Statement

Currently, the MDI values have a skewed distribution to the left and the effective range is less than was originally intended. Originally, the MDI was meant to be a normalized curve with a mean value of 50. In Figure 5, the numbers of occurrences that specific MDI values are assigned to a CATCODE are plotted against the MDI values in bins of five (Avery, 2013).

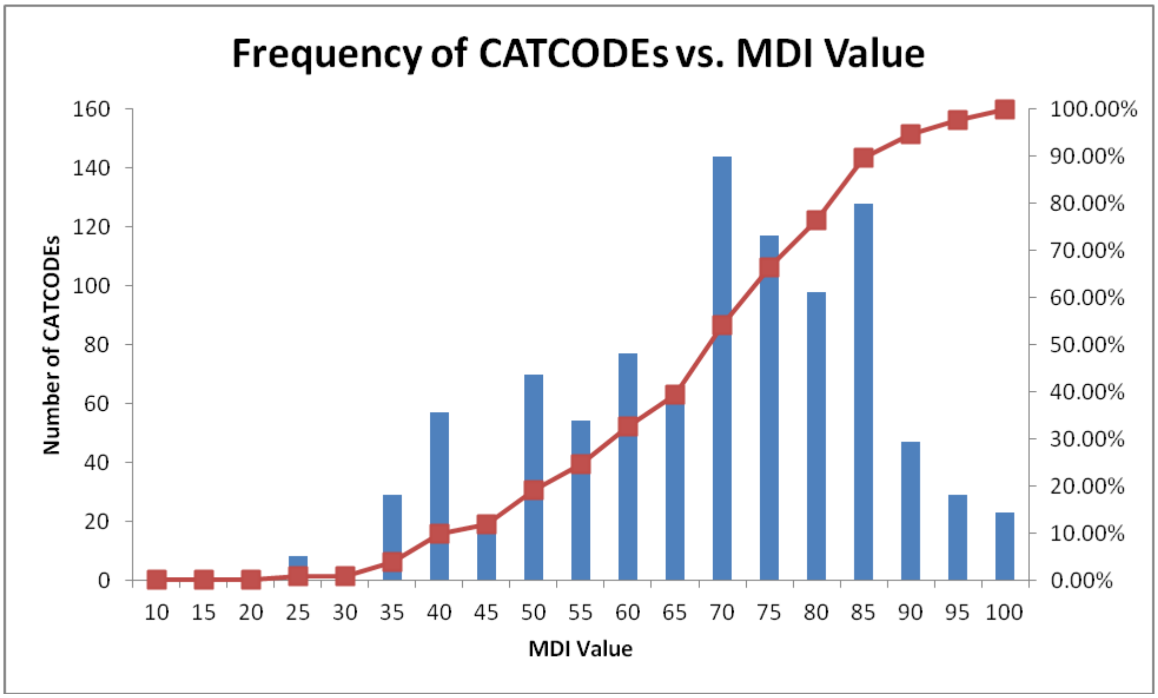


Figure 5. USAF CATCODE Distribution vs. MDI Values (Avery, 2013)

Air Force Civil Engineer Center (AFCEC) recognized there was an issue with the MDI values in the fall of 2013 (Avery, 2013). In response to the issue, AFCEC created a working group to produce a rule set for the career field. The rule set would give the proper guidance to correct an incorrect MDI at all levels. This effort would assist in identifying improper MDI values for specific buildings and ensured the identified facilities receive funding. Although this addresses the issue of individual MDI values, there is still a concern that inflation may continue without a method to govern the distribution of the MDI values. If the current inflation continues, the effective range of the metric decreases, thereby reducing the decision-making value.

Research Objective and Investigative Questions

Given the problem stated above, this research focuses on answering the question, "How can AFCEC create a process to prevent MDI value inflation while maintaining a usable metric for funding decisions?" To help address the research question, four investigative questions were developed to help provide a complete answer. These investigative questions were:

1. What are the inputs needed to define the MDI value of a building?
2. What weight should be applied to each of the inputs when assigning an MDI value to a facility or asset?
3. What is the desired distribution of the MDI values?
4. According to CE SMEs, how should the MDI be applied to the prioritization of infrastructure funding decisions?

The questions mentioned above were developed in an effort to better understand the MDI tool, as well as how the metrics produced by the MDI system should be applied in the CE career field. The current MDI does not have a methodology other than comparing a specific asset's MDI to another asset's MDI. Keeney (1996) warns against this approach by stating, "focusing on alternatives is a limited way to think through decision situations. It is reactive, not proactive." (Keeney, 1996:537). As a solution to the alternative-focused thought process, Keeney suggests that decision-makers should focus on desired values when making decisions. Once these values have been identified, the interactions between the values should also be identified to better understand the opportunity accompanying the decision. In establishing a metric, determining the proper usage is vital to creating the decision-making system. After clearly identifying the definition and proper usage of the MDI metric system, the research can provide AFCEC with a metric to implement funding decisions relating to the Air Force infrastructure portfolio.

Methodology

To answer the questions above, the research employed two methodologies: a Delphi study and Value Focused Thinking (VFT). The Delphi method was performed with the help of CE's Senior Leaders. The Delphi method takes advantage of subject matter experts' (SME) knowledge and experience in an iterative process to provide the research with a well-informed decision towards policymaking. Throughout the Delphi method, a VFT method was applied to help develop a framework to assist in producing the MDI values aligned with the Air Force's goals rather than comparing each asset to all other assets to create a value.

Assumptions/Limitations

The business rules published on 29 January 2014 by AFCEC established a new prioritization model (AFCEC, 2014). The MDI metric is one of the inputs for the prioritization model. The application of MDI in the model is the main driving factor in this research effort. If a new prioritization model is developed, the MDI metric will need to be revisited to ensure it reflects the desired information. The research assumed all facility conditions and commander's preferences are accounted for by the other metrics applied to the funding model. The research goal was to correct the overall MDI distribution problems, so it was not be able to address all individual infrastructure scenarios.

Overview

This chapter addressed the challenges associated with infrastructure funding and more specifically the challenge the Air Force faces with the current MDI metric. This thesis follows a five-chapter format. Chapter II summarizes the literature reviewed throughout the research. Chapter III addresses the Delphi and VFT methodologies used to suggest the new MDI model. Chapter IV looks at the data acquired through the Delphi methodology and how the data was applied to create a VFT model in addition to answering the research questions. Finally, Chapter V summarizes the results of the research and suggests additional research streams.

II. Literature Review

This chapter provides background material related to accomplishing, creating, and using an Asset Prioritization Index (API). The first part of the chapter focuses on the application of the API approach to federal assets and the creation of the Mission Dependency Index (MDI) metric. A background on the Naval Facilities Engineering Command (NAVFAC) MDI model is given to show a specific federal application. The second section addresses examples of how the private industry has approached creating an API. Specifically, the private industry methods examined include: risk based investment trade-off, American Society of Testing Materials (ASTM), and Massachusetts Institute of Technology (MIT). The chapter concludes with a summary of the methods reviewed.

Federal MDI Approach

The requirement for an MDI value application to federal infrastructure portfolios originated from Executive Order 13327 which mandated that federal "agencies shall recognize the importance of real property resources through increased management attention, the establishment of clear goals and objectives, improved policies and levels of accountability" (Executive Order 13327, 2004:5897). To fulfill the requirements of the EO, federal agencies had to establish asset management (AM) practices. Specifically, EO 13327 charges organizations to take actions to prioritize assets to "improve the operational and financial management of the agency's real property inventory" (Executive Order 13327, 2004:5898). When prioritizing actions, the executive branch adopted the risk management approach of measuring probability and consequence. The International Infrastructure Management Manual reinforces this approach stating, “A combination of likelihood and consequence of failure can provide an overall measure of the level of risk” (New Zealand Asset Management Support, 2011). The executive branch adopted the concept of an API and created the term MDI to attempt to assign each asset to the mission it supports. Specifically, the MDI was meant to identify the consequence of an individual asset failing. In the National Academy Press report titled, “Committing to the Cost of Ownership,” it is made clear that unlike private businesses, when a defense asset fails, the potential consequences include the same risks the private sector encounters, in addition to a loss in readiness and a “domino effect” due to the interconnectivity of the military systems (National Academy Press, 1990). These defense unique consequences could lead to breaches in national defense (National Academy Press, 1990). The literature reveals different organizations of the government initially approached assigning consequences to resources differently (National Park Service, 2013; Antelman, Dempsey, & Brodt, 2008; Madaus, 2008). Over time, the NAVFAC method was overwhelmingly adopted by the Navy, Coast Guard, Army, and National Aeronautics and Space Administration (Grussing et al., 2010). The NAVFAC approach is examined in the following section.

NAVFAC MDI Model

The model developed by the NAVFAC measures the consequences of facility failure by examining interruptability, relocateability, and replaceability (Antelman, Dempsey, & Brodt, 2008). The NAVFAC model uses a structured survey (see Appendix A) given to commanders to establish how important each of their assets is to their mission. It also determines how important other commanders’ assets are to their mission. Using the structured survey, the MDI team would apply the values created from the responses to the matrix in Figure 6 and determine the score for mission dependency within an organization (MD_{within}). Similarly, the MDI team would apply the responses acquired about other mission sets to the matrix in Figure 7 to determine the score associated with mission dependency between organizations ($MD_{Between}$).

MISSION INTRA-DEPENDENCY SCORE

MD_W		Q1: Interruptability			
		Immediate (24/7)	Brief (min/hrs)	Short (<7days)	Prolonged (>7days)
Q2: Relocateability	Impossible	4.0	3.6	3.2	2.8
	Extremely Difficult	3.4	3.0	2.6	2.2
	Difficult	2.8	2.4	2.0	1.6
	Possible	2.2	1.8	1.4	1.0

MD_W = Mission Dependency Within a Command's AoR

Figure 6. NAVFAC Intra-Dependency Risk Assessment Matrix MD_{within} (Antelman et al., 2008)

MISSION INTER-DEPENDENCY SCORE

MD_B		Q3: Interruptability			
		Immediate (24/7)	Brief (min/hrs)	Short (<7days)	Prolonged (>7days)
Q4: Replaceability	Impossible	4.0	3.6	3.2	2.8
	Extremely Difficult	3.4	3.0	2.6	2.2
	Difficult	2.8	2.4	2.0	1.6
	Possible	2.2	1.8	1.4	1.0

MD_B = Mission Dependency Between Commands

Figure 7. NAVFAC Inter-dependency Risk Assessment Matrix $MD_{between}$ (Antelman et al., 2008)

After collecting the values from the matrices above, the NAVFAC team averaged the responses from the various agencies, counted how many agencies consider each asset to be mission critical (n), and then placed all of the variables into an equation to produce the proper MDI value. The formulation shown in Equation 1 is used to calculate the MDI for each asset. The values for MD_{Within} and $MD_{Between}$ are the values retrieved from the matrices in Figure 6 and Figure 7, respectively. The n is evaluated using a natural log function to reflect the law of diminishing returns. As the equation suggests, the structured survey must be accomplished for each asset. Figure 8 displays the weight associated with the three inputs and brings attention to the local level, which has the most input toward the asset's MDI value.

$$MDI = 26.54\left[MD_{Within} + 0.125MD_{BetweenAverage} + 0.1Ln\left(n\right)\right] - 25.54 \quad (1)$$

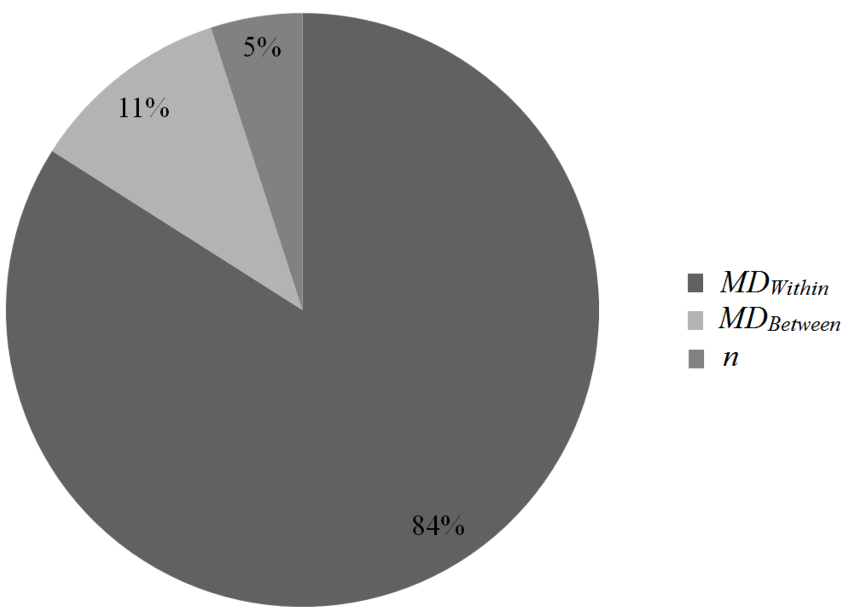


Figure 8. NAVFAC Model Variables Weights toward MDI value

This approach requires a survey team approximately one week and $40,000 to $75,000 per site to accomplish the required data acquisition to make the model accurate (Grussing et al., 2010). Although this model requires continual financial resources and man-hours to maintain, "the MDI has been recognized by the US General Services Administration in 2003 as a 'Best Practice'" (Antelman et al., 2008). As a result, the United States Coast Guard (USCG), National Aeronautical and Space Administration (NASA), and the United States Army (USA) have adopted this model (Grussing et al., 2010).

Although this model produces a usable product, it has four logistical challenges associated with it. The first challenge is the availability of a database powerful enough to store and produce the required queries given the large amount of data required to provide an accurate input. The United States Navy has 111 bases, and each base must input the dependence variable of all the other base's facilities (Department of Defense, 2013). Because of this, there can be up to 111 inputs per asset for the $MD_{between}$ value. If the Air Force adapted this method, there would be up to 185 inputs for each asset (Department of Defense, 2013). To assemble this amount of information, the database for the Air Force would need to be around three times bigger than NAVFAC's database because of the additional information associated with identifying all of the relationships.

The second logistical challenge focuses on cost. When leadership, missions, or operations tempo change, the structured survey must be re-accomplished. As Grussing et al. (2010) estimates, the cost associated with this method is $40,000 to $75,000 per base. An optimistic estimation of the initial expenditure for the Air Force, assuming that leadership stays in place for 3 years and the surveys cost $40,000 would, be $7.4M. To account for leadership, mission, and operations tempo changes, an annual fee for this type of system could be upwards of $2.5M. The annual fee accounts for the assumption that one third of the leadership changes every year, thus driving the need for the survey to be re-accomplished. For a pessimistic estimate, assumptions were that leadership changed every 2 years and a survey cost of $75,000, thus leading to an initial expense of $13.9M with an annual fee of $6.9M. If the annual amounts of funds are not maintained in the budget, the MDI values may not be maintained properly.

The third logistical challenge involves the lack of proper CATCODE assignment. This concern only affects the model when it is applied at the CATCODE level instead of the asset-specific level. For example, CATCODE 442421 is a 'controlled humidity warehouse.' This assignment accurately identifies the majority of assets in that category; however, it does not identify a facility that may support a unique mission set such as special operations or cyber warfare assets. The unique mission sets may require the MDI value to be greater than 59 to reflect the relationship to the mission properly. Other CATCODES exist for warehouses that have higher MDI values to more accurately reflect the specific asset. These corrections will need to take place at the base level by the Real Property Office to ensure proper identification of each facility.

The last logistical challenge accompanying this model is educating leadership to answer the survey consistently. To ensure consistency, the NAVFAC uses two teams to minimize the variability among survey results. The Air Force would need to determine a procedure to ensure the model was applied consistently at all installations. This procedure could be achieved by a specific set of business rules, or a traveling survey team much like the NAVFAC. Each of the logistical challenges presented need to be addressed for this model to function as intended for the Air Force.

Private Industry Asset Prioritization Index Applications

Three private methods were researched to see if they could be adopted by the Air Force. The first method, risk-based investment trade-off approach, examines a situation where the asset is functional and compares it to a situation when the asset is broken. The difference in capacity is the value used to prioritize facilities. The second method requires pair-wise comparisons of all the alternatives to determine the overall and relative importance values. The last method involves creating a model regardless of inputs and then applying the validated model to decisions. The following sections will address each method in further detail.

Risk-Based Investment Trade-Off Approach

Taillandier, Sauce, and Bonetto (2009) followed a different approach to quantifying consequences for decision-making. Their research observes the mission impact of an unintended event (UE) occurring and the difference in potential damage. Two scenarios with input from the tactical and managerial level were examined to measure the potential damages. In one scenario, an event occurred and in the other scenario, no event occurred. The difference in potential damage displayed the amount of consequences associated with an asset. When comparing all assets' potential damage differences, the decision-makers could readily identify the most important asset. This methodology is cumbersome, but it reflects the views from multiple levels of managers associated with the asset. Figure 9 shows the model to help predict the consequence amount.

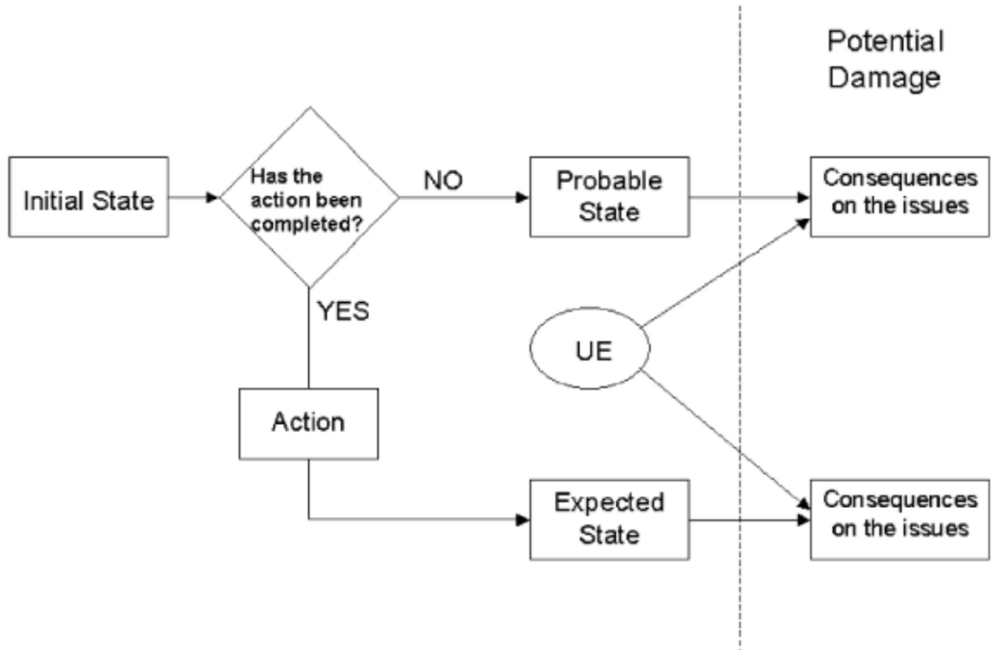


Figure 9. Decision Model to Produce a Consequence Domain
(Taillandier, Sauce, & Bonetto, 2009:789)

Patterson and Apostolakis (2007) applied a similar methodology in an attempt to identify critical locations across multiple infrastructures. The authors created a metric, the Birnbaum importance measure (IM), represented by Equation 2. "The Birnbaum IM describes the change in risk to user *j* for infrastructure *k* when element *y* switches from available to unavailable" (Patterson & Apostolakis, 2007:1189).

$$B_{ykj} = U^{+}_{ykj} - U^{-}_{ykj} \qquad (1)$$

The U^{+} variable represents the number of failed elements contributing to a system's failure, and the U^{-} variable represents the elements still in working condition. This method shows that if certain assets in the system malfunction, there is a cascading impact on the user. After the

Birnbaum IM is assigned to each building in the system, the critical nodes in the infrastructure can be identified. While the way it assigns the IM to the buildings is similar to Taillandier et al. (2009), this method finds the consequence of failure of all infrastructure sections in a portfolio.

The risk-based investment trade-off approach could be applied to Air Force facilities, but three challenges would have to be overcome. The first challenge would be to establish a rule set for consistency when evaluating different scenarios. Determining how many levels of asset managers to involve in determining the consequence index would be the second challenge. Asset managers at each level of an organization have different agendas and assigned missions, which affects how he or she views the importance of an individual asset. The final challenge would involve identifying a metric to help analyze all of the consequence indexes. As the authors point out, "Converting every data into a monetary equivalent data system does not make it possible for decision-makers to put the different kinds of consequences (human, commercial, material, etc.) in perspective" (Taillandier, Sauce, & Bonetto, 2009:789). If these challenges are addressed correctly, this methodology could be applied to the Air Force's asset portfolio.

American Society of Testing Materials (ASTM) Model

The ASTM model presented in standards E1765-11, Standard Practice for Applying Analytical Hierarchy Process (AHP) to Multi-attribute Decision Analysis of Investments Related to Buildings and Build Systems, and E2495-13, Standard Practice for Prioritizing Asset Resources in Acquisition, Utilization, and Disposition, provides a systematic approach on how to produce a multi-attribute decision analysis tool. "The practice presents a procedure for calculating and interpreting AHP scores of a project's total overall desirability" (ASTM, 2011:1). The standard demonstrates how to produce a value tree to make decisions. In addition to the value tree solution, it displays an example of how to perform AHP on a “finite and generally small set of discrete… options” (ASTM, 2011:2).

As shown in Figure 10, to perform an AHP analysis, all assets must be listed in a matrix comparing one asset to all others (i.e. pair-wise comparison). When the weights are assigned, the relative importance is given to each pairing using a scale. After all of the paired comparisons among alternatives are complete, the weights of each alternative are created by solving for the eigenvector, represented as *e** in Equation 3. M is the matrix of paired comparisons and λ_{max} represents the principal eigenvalue of the matrix M. Once *e** is found, its value represents the relative weight of that item compared to all other items appearing in the analysis. If all of the *e** values are sorted, a prioritized list will be created.

$$\lambda_{max} e^* = M e^* \qquad (2)$$

To properly apply the AHP process to the facilities in the Air Force, a matrix would need to be created with $n(n-1)/2$ elements, where n represents each facility. If the AHP method was applied using all 139,556 facilities, it would require over 9 billion paired comparisons to accomplish. If the analysis was accomplished at the CATCODE level, where there are 966 categories, it would require only 466,095 paired comparisons. Although requiring fewer comparisons overall, choosing the CATCODE method would still require a large amount of data collection and accompanying decisions made at the appropriate level. The final way to appropriately use the AHP would be to use it within each MDI value. This application would help establish a relative mission importance within each MDI ranking. The Air Force could use this methodology if it was limited to a level that would result in a manageable amount of paired comparisons. The level that produced the manageable amount of comparisons needs to be determined by the leadership responsible for allocating resources. If a level is selected without the resources to support it, this method will be unattainable. Overall, the AHP method could prove to be the most accurate method of modeling all assets against each other to produce a prioritized list, but it would require a tremendous amount of participation from leadership to achieve the desired outcome.

	Alternative 1	Alternative 2	…	Alternative *j*	Alternative *k*	…	Alternative *n*
Alternative 1	1	Desirablity of Alt. 1 versus Alt. 2	…	Desirablity of Alt. 1 versus Alt. *j*	Desirablity of Alt. 1 versus Alt. *k*	…	Desirablity of Alt. 1 versus Alt. *n*
Alternative 2	Desirablity of Alt. 2 versus Alt. 1	1	…	Desirablity of Alt. 2 versus Alt. *j*	Desirablity of Alt. 2 versus Alt. *k*	…	Desirablity of Alt. 2 versus Alt. *n*
…	…	…	1	…	…	…	…
Alternative *j*	Desirablity of Alt. *j* versus Alt. 1	Desirablity of Alt. *j* versus Alt. 2	…	1	Desirablity of Alt. *j* versus Alt. *k*	…	Desirablity of Alt. *j* versus Alt. *n*
Alternative *k*	Desirablity of Alt. *k* versus Alt. 1	Desirablity of Alt. *k* versus Alt. 2	…	Desirablity of Alt. *k* versus Alt. *j*	1	…	Desirablity of Alt. *k* versus Alt. *n*
…	…	…	…	…	…	1	…
Alternative *n*	Desirablity of Alt. *n* versus Alt. 1	Desirablity of Alt. *n* versus Alt. 2	…	Desirablity of Alt. *n* versus Alt. *j*	Desirablity of Alt. *n* versus Alt. *k*	…	1

Figure 10. Example of a matrix of Paired Comparisons among Alternatives (ASTM, 2011)

Massachusetts Institute of Technology (MIT) Model

To ensure the infrastructure support budget is applied to the correct assets responsibly, MIT developed a model to "apply limited resources to the most important needs first, support consistent, repeatable, and defendable prioritization decisions, consider the impact of risk on these decisions, be flexible and easy to use, and enable careful and thoughtful consideration of alternative choices while supporting consensus" (Karydas & Gifun, 2006:85). The process MIT developed combined three different methodologies. The entire process "developed originally at MIT for the prioritization of safety and operational experience in nuclear power plants was [then] adopted and modified by facilities for its use" (Karydas & Gifun, 2006:85). The prioritization process consists of six steps: develop the project selection process, define impact categories and performance measures, weight impact categories and performance measures, define and weight constructed scales, check for consistency, and check for validity and reliability.

The first step is to develop the project selection process. In this step, MIT's decision-makers placed the project in one of the four categories shown in Figure 11 (Karydas & Gifun, 2006). When the board of decision-makers is presented with a project, it will be prioritized only if it has a moderate to high cost and does not need to be accomplished immediately. The projects that must be accomplished immediately for safety reasons or other factors are placed in the "Must Do" category. On the other end of the spectrum, if a project does not add any value to the mission of the campus, it is placed in the "Must Not Do" category. If the project is small or the request is accomplishing preventive maintenance, the staff will accomplish it as labor becomes available.

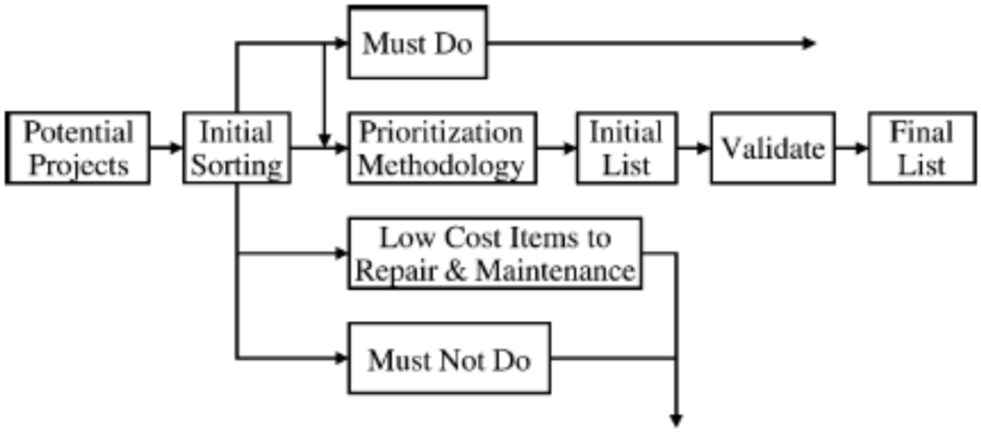


Figure 11. MIT Prioritization Process Map

After the project selection process is defined, the decision-makers develop impact categories (IC) and performance measures (PM). In MIT's case, the board created six impact categories and ten performance measures. Each category and measure is defined specifically to help the members of the board understand the true intention of the model. The definitions of the categories for MIT are shown Appendix B. After all desired performance measures are identified, a weighting scheme is applied using an analytical hierarchy process (AHP). The results of the MIT AHP are shown in Figure 12. Each value shown is out of a total possible value of 1.0 to show the importance of each category in comparison with other categories.

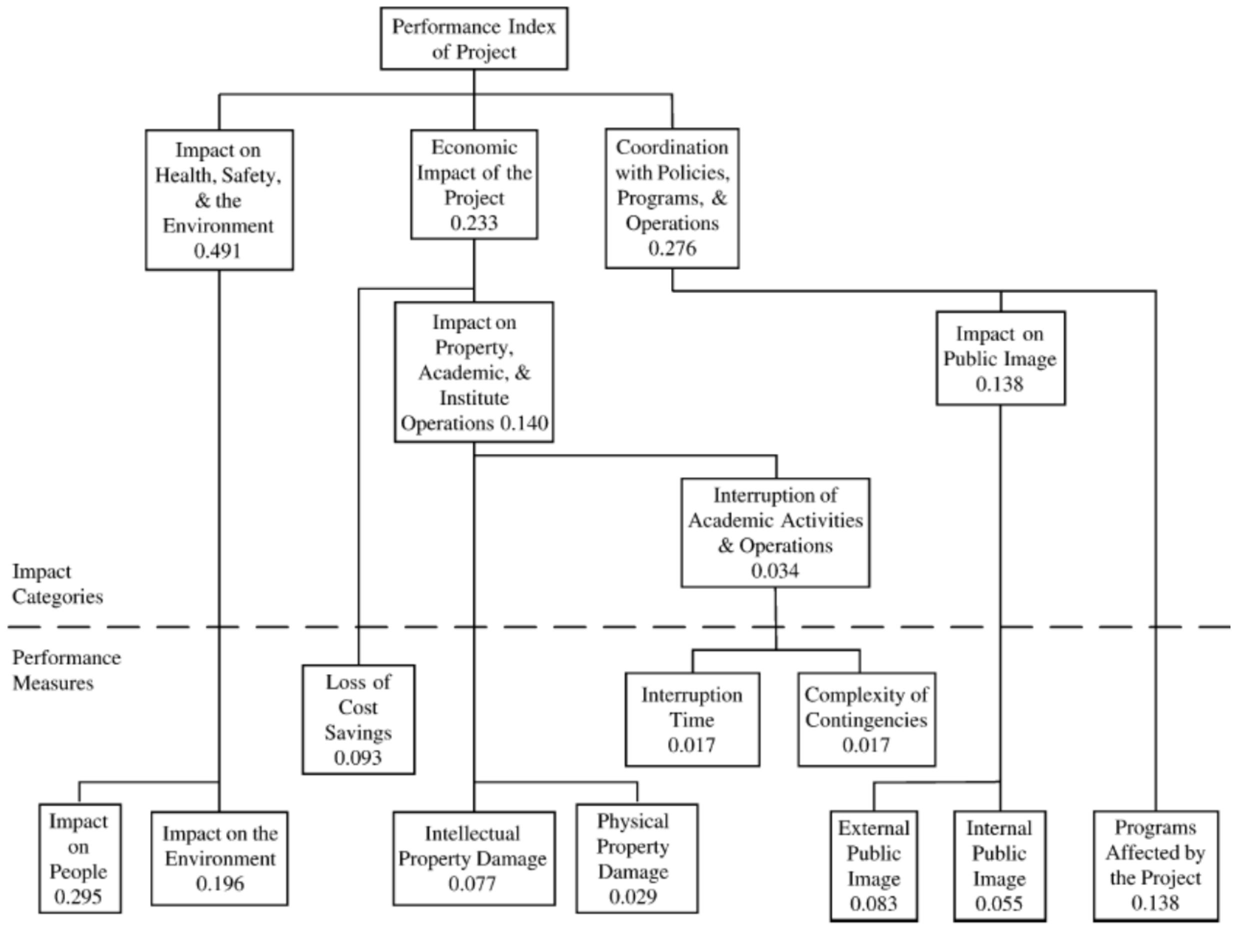


Figure 12. MIT Prioritization Value Tree
(Karydas & Gifun, 2006:88)

Following the weighting of all the performance measures, the board then defines and weights the constructed scales within each performance measure individually. The authors used three levels of values for each performance measure. The scale included specific descriptions to ensure reliability. Each level on the scale had an individual weight developed from a value function. The value function is an equation developed from the input of experts to assign various weights to the levels within a measure (Kirkwood, 1997). In MIT's application, disutility curves were used as the value functions to "depict Facilities preference for risk adversity" (Karydas &

Gifun, 2006). The disutility curves were developed by the respective subject matter experts and then verified by the board prior to being incorporated into the overall model. An example of the different levels and the disutility curve is shown in Figure 13.

Constructed Scale -Impact on the Environment		
Level	Description	Disutility
3	Major environmental impact	1.00
2	Moderateenvironmental impact	0.34
1	Minor environmental impact	0.04
0	No environmental impact	0.00

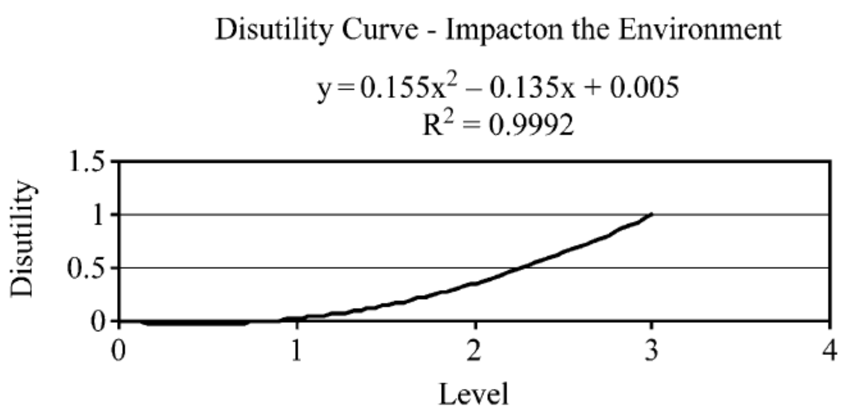


Figure 13. Example of MIT Constructed Scale and Disutility Curve
(Karydas & Gifun, 2006:92)

The authors identified the final steps of this methodology as checking for consistency, validity, and reliability. MIT accomplished the final steps by leveraging the Expert Choice® application and benchmarking. After all of the steps are accomplished, the model can be applied with the use of decision-makers. Karydas and Gifun (2006) stated that even after the model had been applied to all projects to provide prioritization, the board could revisit the list to provide one final check on the prioritization to ensure each project was ranked as desired. This model applies a defined scale to each performance measure to better prioritize a portfolio of assets. If an organization systematically defines the impact categories, performance measures, and value functions, this model could be used as a template for implementation.

The MIT model methodology has been applied to a number of systems to accurately capture the risk associated with an asset. Specifically, Koonce, Apostolakis, and Cook (2008) applied the model to the North American Electrical Reliability Council's bulk power grid from the point of view of the electric supplier. Their analysis provided a "systematic process that produces a ranking of elements within the bulk power grid for random failures and malevolent acts" (Koonce, Apostolakis, & Cook, 2008:182). The advantage of focusing on the values associated with an asset and creating a model from those values is that the method assists the model creator in eliminating bias toward a specific asset and encourages portfolio optimization.

With some modification, the model could be used as a starting point to provide a better funding decision model for Air Force projects. Specifically, it could be applied to develop a set of performance measures relating to the MDI. After each performance measure is established, a value function can be produced to display the differences among similar assets that otherwise would be rated similarly. While the MIT model helps standardize responses, there are three issues with its implementation in the Air Force. The first issue is determining the appropriate level for the final deliberations to occur in the Air Force. When the inputs are placed into the model, the board at MIT verifies a rough draft of the prioritization list. This methodology may have scaling issues when trying to adapt it to the Air Force. If the prioritization list were verified and presumably changed at the wing, MAJCOM, and HAF levels, the original intent of the order of the projects may change completely during the bureaucratic process. The second issue involves accessibility to the project champion or the subject matter experts (SME) throughout the deliberations stages. At the lower levels, the access will not be an issue; however, at the strategic levels, the staff will often not have the appropriate time to talk to every SME about each project. The final implementation issue is to define adequately each performance measure and level on the constructed scale. If the definitions are not distinguishable among various levels, the interpretation by the user could threaten the validity of the entire prioritization model. To successfully adopt this model, each of these issues would need to be addressed.

Summary of Private Industry Asset Prioritization Index Applications

All three methods presented have worked in specific applications of the private sector. The common theme when adapting the methods to the Air Force portfolio is scaling. All methods require data collection, analysis, and storage that will add cost to the present methodology. Despite these challenges, all of the methods would provide a more defendable process in creating asset-specific MDI values.

Chapter Summary

In this literature review, four different approaches to developing an MDI metric were examined. Each method had pros and cons and required differing amounts of labor and resources to establish and maintain. The common theme developed from the models was the importance of knowing the capability the asset provides to the mission. Once each asset is tied to a function, the importance of it not being there could be addressed quickly and the effects of it not functioning would be clear. In the next chapter, the methodology for how the research creates inputs for the MDI metric is discussed.

III. Methodology

After studying government and private industry methods to establish an asset prioritization index (API), the Massachusetts Institute of Technology (MIT) model was adopted for this research. This methodology was selected because of the consistent process created while still allowing the leadership to revisit the prioritization before the distribution of funding. The MIT approach involves a group of stakeholders indentifying criteria to establish a Value Focused Thinking (VFT) model. The desired effect of this research was to provide a method that, when all assets have been assigned an MDI value, will result in the desired, normal distribution with no inflation. As stated before, the current MDI system operates in the range of 32-99 because of inflation. The goal of this research was to find an appropriate method that returns MDI values ranging from 1-100. The variability and effective range are important because these characteristics inform the decision-makers about the differences between assets. When an index has a smaller range, the diversity of the portfolio is not demonstrated when compared to the larger range. Guided by the desired outputs of the process, a Delphi study was performed to identify the inputs for the MDI metric. The Delphi questionnaire's data was employed with the Value Focused Thinking (VFT) method to create the process of determining an asset's MDI value.

Value Focused Thinking Method

A VFT study is a methodology used for gathering data about inputs of a process to generate a model that ties strategic goals to routine operations (Keeney, 1992). VFT pre-establishes the different input values applied in organizational decision-making instead of relying on alternative focused thinking (AFT), the process of selecting the strongest alternative. VFT involves "a shift to this way of thinking about decisions… because values guide not only the creation of better alternatives but the identification of better decision situations" (Keeney, 1996:538). Figure 14 demonstrates all of the characteristics of VFT.

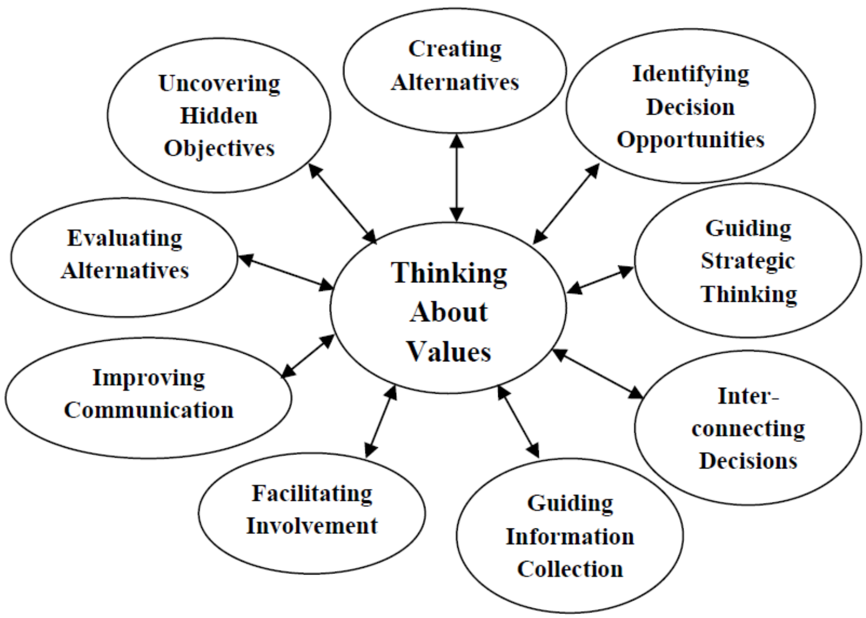


Figure 14. Overview of Value Focused Thinking
(Keeney, 1992:24)

León (1999) performed studies to further outline the benefits of VFT (1999). These benefits included the notion that, alternatives with more innovative characteristics are included, the range of alternatives included becomes wider, the future consequences of decisions are taken more into account, alternatives that at first glance would not be considered are integrated, and consequences that are more desirable are considered. Once produced, a VFT model allows decisions to be made based on established criteria rather than using a comparison of all alternatives in an individual subjective manner (Keeney, 1992).

The VFT process also has a number of challenges identified by Keeney (1996). The first challenge is the initial identification of fundamental objectives for the organization. The team producing the VFT model needs to ensure the objectives identified tie to the company's goals rather than a specific alternative. The second challenge is the initial time required to produce the VFT model. Keeney emphasizes that if these challenges are overcome, the VFT model will produce superior results when compared to the AFT.

Delphi Method

In 1999, Rowe and Wright (1999:354) characterized the three main features of a Delphi study as "anonymity, iteration, [and] controlled feedback." These features are achieved through multiple rounds of questions in which expert opinions are gathered and discussed within the group in an effort to garner consensus and/or highlight differences in opinions on the topic of discussion. Throughout the iterative process, inputs are determined to identify and maximize decision opportunities. Figure 15 shows the typical flow of the steps in a Delphi process.

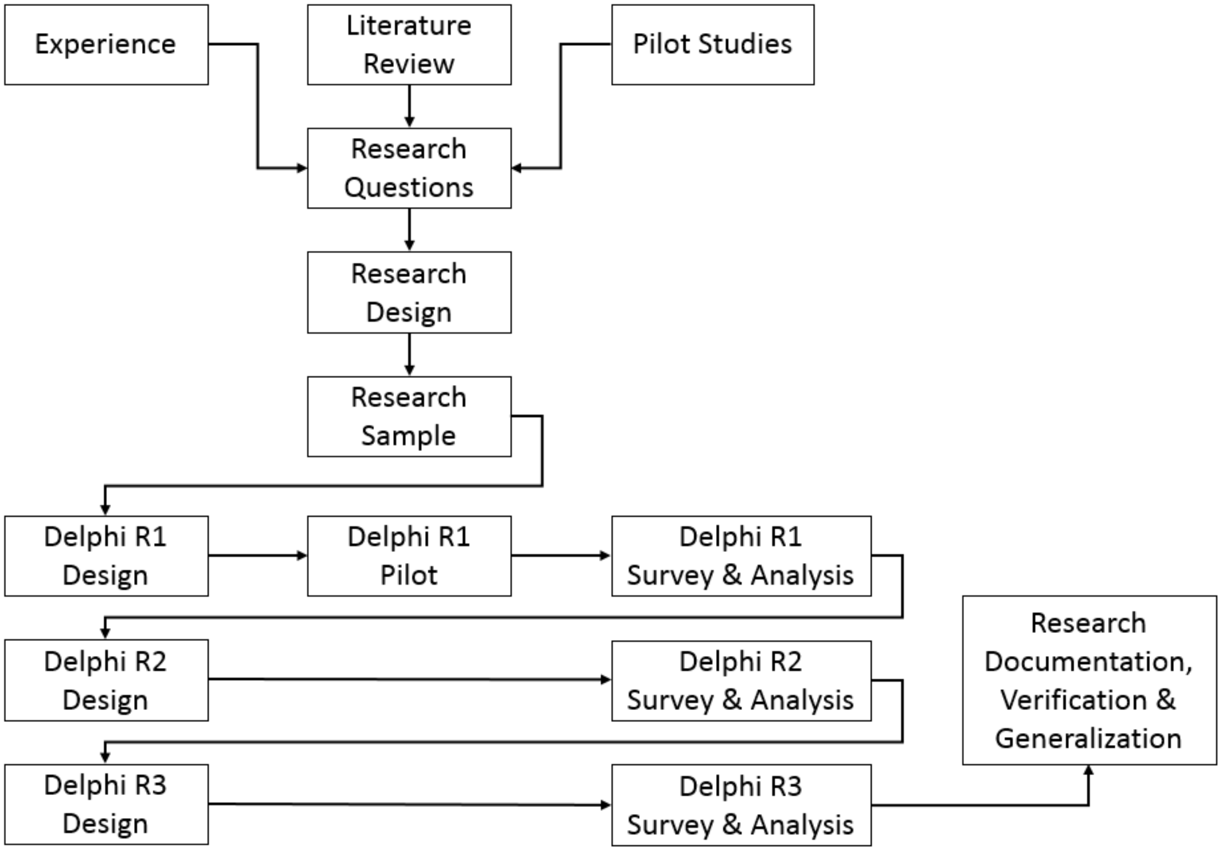


Figure 15. Steps of a Delphi Process
(adapted from Skulmoski et al., 2007:3)

The Delphi rounds produced inputs for the MDI values, as well as helped develop an importance associated with each input. The Delphi collected questionnaire data from Air Force CE senior leaders and SMEs. The first round was focused on identifying issues with the current MDI system as observed by the panel members. After the issues were identified, the second round was focused on identifying possible inputs that should be considered when creating the MDI metric. The third round attempted to bring the panel members to a consensus on the values required to produce a usable MDI value. A copy of the study's overview that was provided to the Delphi participants is in Appendix C as well as the letter from AFCEC in Appendix J. After all rounds were complete, the data gathered from the Delphi was used to create and produce a VFT model.

Delphi Panel Composition

This study selected CE Career field leaders and subject matter experts (SME) as panel members because they are the experts on how to manage the USAF infrastructure. To qualify as a senior leader, the participants needed to be a senior Field Grade Officer or equivalent to represent the strategic level of decision-makers, have a minimum of 15 years experience managing infrastructure assets, and have a working knowledge of the CE prioritization model. To be considered a subject matter expert, the panel member must have a minimum of 3 years experience prioritizing infrastructure asset projects using MDI as one of the inputs, working knowledge of the CE prioritization model, and specific knowledge of CE funding and prioritization actions in support of public infrastructure. The SMEs only required 3 years of experience with MDI because MDI has only been applicable in the Air Force prioritization efforts for 6 years. AFCEC provided a group of individuals that met these requirements.

The secondary reason the panel members were selected was these individuals were a sample of convenience. They were identified by AFCEC as possible participants because of ease of access (they were part of the organization), and their knowledge on the subject matter. This sample provided the data necessary to conduct the Delphi study. The Delphi questionnaire's data retrieved then supported the development of the VFT hierarchy. The inputs for the first round of the Delphi were created from the literature review; subsequent rounds then adapted questions and issues as the participants identified concerns. The goal of the study was to receive feedback from each mission set (MAJCOMs) and the overall corporate goals (AFCEC). The feedback from different backgrounds assisted in producing the inputs for the MDI metric that reflect the importance of an infrastructure asset in a repeatable manner.

Analysis of VFT Application

After the inputs were collected through the Delphi, the inputs were used to create the impact categories (IC) or values of MDI. The ICs are the characteristics that should be addressed when creating the MDI of the asset. After each IC was identified, the performance measures (PM) were determined. The PMs address how each IC is measured. The ICs and PMs were placed into a hierarchy as shown in Figure 12. “Desirable properties for a value hierarchy include completeness, nonredundancy, decomposability, operability, and small size” (Kirkwood, 1997:16). The completeness characteristic is when all layers of the hierarchy can represent every aspect of the desired decision (Kirkwood, 1997). Nonredundancy must be met in a hierarchy to ensure there is no overlapping between the tiers (Kirkwood,1997). In other words, this requirement states that all inputs in a tier must be mutually exclusive of each other. Decomposability can also be described as independence. When a value is being determined for one objective in the hierarchy, the resultant value cannot affect another objectives value. The operability and small size characteristics ensure the hierarchy can be easily used by the desired audience (Kirkwood, 1997). To achieve all of these properties, the first five steps of Shovaik’s (2001) ten-step VFT process shown in Table 1 were used. The scope of this research was focused solely on providing a repeatable methodology to develop the Air Force MDI values. It did not address the implementation of the model and therefore only addressed the first five steps of the VFT process.

Table 1. Ten Step VFT Process (Shoviak, 2001)

Step	Description
1	Problem Identification
2	Create Value Hierarchy
3	Develop Evaluation Measures
4	Create Value Functions
5	Weight Value Hierarchy
6	Alternative Generation
7	Alternative Scoring
8	Deterministic Analysis
9	Sensitivity Analysis
10	Conclusions and Recommendations

The VFT method allows there to be unique distributions and weights applied to reflect the overall desires of the leadership. Because of this characteristic, the MDI values produced can be adjusted to follow the desired range and distribution identified by the Delphi panel. In addition, the MDI metric is meant to measure criticality in a similar value across the asset portfolio. Depending on priorities, some mission sets or locations may be more critical.

Threats to Validity and Reliability

The methodology presented relies heavily on the Delphi panel balancing the corporate goals with the mission-specific goals. Because the population size is small, the validity of the weights is threatened if the panel cannot reach a consensus. The reliability is threatened if the PMs are not defined properly. If the different levels of the PMs do not have distinct definitions, each user of the model could produce a separate MDI value for the same asset based on the user's interpretation of the definitions. If the model yields different results for the same asset from run to run, the PMs will need to be made clearer to avoid the ambiguity causing the inconsistency.

Chapter Summary

The research used two different methodologies at different stages to determine the best MDI model for the USAF. The methodologies were a combination of qualitative and quantitative approaches in an effort to capture the art and science aspects of asset management. The resulting VFT model, developed with feedback from the Delphi panel, should have the capability to adapt to changes in the leadership prioritization while providing a standardized process to produce the MDI metric.

IV. Analysis and Results

This chapter addresses the results and themes from each round of the Delphi approach, as well as the resulting value focused thinking (VFT) model that was developed. Each round of Delphi questions are in Appendixes D, F, and H, respectively. The specific coding of the answers are in Appendixes E, G and I. The panel members specified by Air Force Civil Engineer Center (AFCEC) were identified to ensure feedback received was from qualified individuals who understand multiple missions throughout the Air Force and how the infrastructure supports varying mission sets. The panel members who participated in all three rounds had a combined experience of over 150 years supporting infrastructure for the public and private sector. These panel members' individual experiences varied from base level to Headquarters Air Force (HAF). The mission sets supported by the members included: Air Force Global Strike Command, Air Force Space Command, National Guard Bureau, Air Education Command, Air Combat Command, Air Force Special Operations Command, Pacific Air Forces, Air Force Materiel Command, United States Air Forces in Europe, Tactical Air Command, and Strategic Air Command. The last two commands in the list of mission sets represented no longer exist; however, they are mentioned to display the wide experience of the panel members. Throughout the rounds, the panel focused on VFT rather than alternative-focused thinking (AFT) to help produce inputs that could apply to any mission set rather than specific mission sets. After each round, the responses were coded and graduate students at the Air Force Institute of Technology verified 10% of the coding as suggested by Lombard et al. (2002).

Delphi Round I

As identified in the Consequence of Failure Playbook (a rule set developed by the Air Force CE Career Field to correct individual MDI values), there are "problematic [categorization code] CATCODEs whose MDIs do not accurately reflect the mission criticality of individual facilities" (AFCEC, 2014). Because of this, the first round focused on identifying the current system's issues and possible inputs into creating a better MDI. One important step in developing the Round I questions was conducting a pilot study. Skulmoski et al. (2007) suggests, "A pilot study is sometimes conducted with the goals of testing and adjusting the Delphi questionnaire to improve comprehension, and to work out any procedural problems." In accordance with this literature's guidance, graduate students from the Air Force Institute of Technology studying engineering asset management validated each question's intent and clarity. A pilot study was conducted for this round and subsequent rounds of the Delphi study.

The results from the first round produced some expected results but also identified unexpected new themes. The panel agreed that the current MDI method provided repeatable, easy-to-use values from a common frame of reference and that it assists leaders in prioritization. The inputs that should be used are identified in Table 2.

Table 2. Inputs to Consider When Developing the MDI Value

Criticality	Air Force Mission
	Local Mission
Consequence of Failure	Mission Degradation
	Fiscally
	Life, Health, and Safety Issues
Redundancy	Air Force Mission
	Local Mission
Replaceability	
Asset Specific	

One panel member pointed out that Air Force mission criticality should be measured by using the Air Force core functions. The core functions of the Air Force are a set of activities that represent the full range of the service's capabilities. These functions are intended to be available for military (as well as non-military) operations around the world. A list of the core functions, as well as the Major Command (MAJCOM) responsible for providing them, is in Appendix F.

The panel identified a number of issues associated with MDI as well. One of the major flaws was the inability to properly identify non-flightline mission assets and the facilities used to support them. Some panel members believed that the inconsistency came from the usage of CATCODEs as the main determinant. The lack of individuality that accompanied the CATCODE method led the panel to suggest that local mission impact was not accounted for in the process. One panel member said, "Relying on the CATCODE system infers that it is good data…I don't believe that is an accurate assumption." Another issue presented was that the current system does not allow an adjustment if there are redundant assets. To be specific, all assets receive the same MDI value whether they are the primary or secondary in support of the mission. The panel posed the question, "What level of the mission is it supporting?" Looking from the Air Force level, losing power to one airstrip may not be an issue; but at the local mission level, it would be important to get the situation remedied. This point of view also revealed that only the local-level experts know the second and third-order effects that occur when a specific asset is no longer usable.

The questionnaire closed by attempting to elicit alternative methods for the MDI. Panel members were asked in an open response question: "Is there another metric that should be used rather than the MDI?" The responses ranged from the "Chief of Staff of the Air Force priority list" to the "Facility Utilization Board" which is a meeting held at each base to determine local requirements. All of the issues the panel addressed helped in creating the second round of questions.

Delphi Round II

Round II was designed to further clarify the themes from the first round, in addition to determining if the individual issues that were identified are prevalent throughout the enterprise. The majority of the Delphi team agreed that both the local and Air Force mission impact should be taken into consideration when producing the MDI metric. All members agreed the Consequence of Failure (CoF), applied in prioritization decisions, can be measured using MDI. The majority of the panel agreed that the MDI value should be asset-specific. The members in favor of having asset-specific MDI values believe that it would assist leaders in prioritizing funding and resource requirements. The others argued that collecting all of the data required to make an asset-specific MDI value would be time and cost prohibitive.

Another issue addressed in this round was MDI inflation. One panel member noted that it would be hard to prevent overall MDI inflation and, therefore, hard to ensure portfolio wide consistency. MDI inflation is currently taking place because of the ability to increase an individual asset's MDI value without the requirement to decrease another asset's MDI value. If this process continues without interference, the entire portfolio's effective range will reduce, along with the decision-making power delivered by the MDI. When reducing inflation, the panel member was concerned that reducing inflation is counter to the effort placed on receiving funding to support assets. This paradox would encourage the local-level decision-makers to not reduce the MDI values of their assets. If all other installations are reducing values and one installation does not, the installation's local assets will rank higher from a portfolio-wide perspective and, as a result, receive more funding. To ensure portfolio-wide consistency, a rule set would need to be published to encourage all installations to reduce their installation's inflation of the MDI.

The next group of questions focused on how to account for redundant assets. One panel member suggested that redundancy should be measured using money. Redundancy defined as a function of money supports the argument: if an asset costs $5, then have an inventory of replacements and do not place any value on redundancy. In contrast, if the asset is a one-of-a-kind item, it might be cost prohibitive to build the asset again. As a result of being one-of-a-kind, the asset would receive a higher weight in the redundancy measure. Another member suggested redundancy should be viewed as a function of mission capacity. If multiple assets exist to ensure the installation can provide the mission required by the commander that must be identified. A panel member explained this by giving the example of "two parallel runways w/similar characteristics, the loss of one [runway] does not drive mission failure…unless they can't generate enough sorties w/one runway." Another panel member made the suggestion to add a coefficient to assets within the same CATCODE. The coefficient would allow the primary, secondary, or tertiary asset MDI values to be adjusted reflect the amount of redundant assets at the specified level. The final suggestion from the panel was that redundancy should be determined at the local and headquarters levels.

The theme of replaceability was addressed in this round. The team identified that replaceability focused on resources available. Money, labor, and time had large roles in determining how replaceable an asset is. These three resources are fluid and hard to identify accurately over long periods in order to use them in an MDI value. The impact on the different mission set was again recognized as an input to replaceability.

In an effort to address the disconnect between the local and headquarters level viewpoints, the panel members were asked if the MAJCOM priority adequately accounted for the local mission in the consequence of failure (CoF) metric. The majority of the panel agreed the local mission was not accounted for by the MAJCOM and that the weightings should adjust over time. A portion of the group thought that only the corrected MDI value should be used as the CoF metric. The other portion of the panel suggested that the weightings should be revisited on a recurring basis to ensure they reflect the overall goals at the Air Force and local levels. The panel was asked if the current process, which allows an individual asset's MDI value to be adjusted to a higher value, leads to the MAJCOM priority and MDI values combining. The majority of the panel agreed that these two inputs were not mutually exclusive. The panel agreed that having an adjustment factor to vary a specific CATCODE within a core function would correct the MDI values of assets not supporting the flying mission set.

The final issue focused on the application of the MDI to utilities and infrastructure that affect numerous assets. The panel suggested three courses of action (COA). In COA 1, for the utility and infrastructure system, assign an MDI equal to the highest MDI for a facility connected to it. COA 2 suggested using a weighted sum or the mean of all the facilities affected by the utility and infrastructure system. A member also addressed that when multiple facilities are affected, the MDI value assigned to the project should increase because of the interconnectivity of the project. The final suggested COA was to address situations on a requirement-specific basis. This COA would need to have a procedure in place to weight the requirements to ensure it does not get misused.

Overall, round II helped clarify the disconnects discovered in the first round. In the development of round II, the feedback from round I implied there might be a division in the panel with one group focused on local influence of the MDI value and the other group focused on the headquarters influence. When analyzing the responses from round II, it became clear that there were two groups. One group focused more on the significance at the local level (micro viewpoint) while the other focused on the significance at the headquarters level (macro viewpoint). Berman's (1978) findings suggest that the implementation of federal policy at the local level lends support to the discovery of two distinct views: micro view (local level) and macro view (global level). Berman (1978:32) believes this issue stems from, "micro-implementation cannot be effective unless local delivery organizations undergo an adaptive process." Berman suggests that without the involvement of the local level in the creation of the process, the local decision-makers will implement the policy to the best of their ability. However, this adaptation of the federal policy may not accomplish the original intention of the policy. The disconnect created when policy is created at the strategic level and applied at the micro level is difficult to remedy without compromise. The last round attempts to guide the panel to a consensus on the inputs that should be addressed in the creation of an asset's MDI.

Delphi Round III

Round III began with a question to apply weights to all of the values identified in the earlier rounds. Table 3 shows the responses for the weights from the five Delphi members who responded in Round III. Table 3 reveals several interesting findings. First, these results clearly show the micro and macro level focus groups. Members A, C, and D weighted the local level higher than the Air Force level, while member E weighted the Air Force level higher. Panel member B gave equal weighting to both the micro and macro level. Second, although cost was identified throughout the first two rounds, no member placed any weight in that category. This indicates that cost does not represent value to the panel for MDI. Although this result was not initially expected, Selart and Johansen (2011) point out that during the decision-making process, solutions created by an AFT group are often focused on cost and solutions created by the VFT group focus more on long-term goals. Third, redundancy received a weight from all panel members-even the member biased towards the micro view; this reinforced the importance of it being a valuable input to the MDI. Finally, only two members weighted "time to replace" and "number quantity of missions impacted." With only part of the panel giving these categories some consideration, this suggests that these values remain important, but to a lesser degree, than categories that received responses from all panel members.

Table 3. Delphi Value Weighting Response

	Panel Member				
Values for the MDI Metric	A	B	C	D	E
Criticality at the Local level	30	40	50	90	25
Criticality of the Core Functions (Air Force level)	20	40	10	5	35
Redundancy	35	10	20	5	15
Time to replace	10	10	0	0	0
Cost	0	0	0	0	0
Number of Local Level Missions Impacted	0	0	10	0	10
Number of Core Functions Missions Impacted (AF level)	0	0	10	0	15

The remaining questions in the round asked the panel three things: what level of commander influence should be the most important; should assets offered by the local community count as redundant; and should the Air Force adapt the NAVFAC methodology. The division in the panel remained when responding to whether a local commander's influence or headquarters commander's influence was more valuable. With regards to redundancy found in the local community, one panel member brought up that quality of life assets that are available off-base (e.g., library) should receive a reduction in their MDI value because the asset is redundant. A portion of the panel believed this could be taken advantage of in order to produce a cost savings. The other members of the panel believed that Air Force installations should be viewed as standalone and provide a complete set of services to the members. The Delphi concluded with a question on whether the NAVFAC model should be adapted, and the panel was spilt on the question. One panel member noted that rather than "Air Force-ize" our system, it would be easier to adopt an existing method. Another believes the NAVFAC method requires too many resources in the current fiscal environment. Overall, round three helped validate the inputs to be placed into the metric's system and affirm the two outlooks on MDI values.

Summary of Delphi Study

The research focus was to provide AFCEC with insight on how to produce a correct MDI value while mitigating inflation. The Delphi team helped provide input in a non-attribution environment to improve the metric. Every round aimed to validate and clarify the metric and environment surrounding its creation. One limitation of these results was that the Delphi group decreased in size for each round. Additionally, due to the audience required to complete the questionnaires, more time was given in each round to receive inputs, thus limiting the number of rounds completed. Finally, the Delphi group's opinions and suggestions are grounded in their experience yielding a bias dependent on this experience. The results should still be used to improve the current conditions despite the accompanying limitations. The following section addresses how the data collected through the Delphi were applied to create a VFT model.

Value Focused Thinking Hierarchy Creation

The Delphi study provided insight into step one, problem identification, of the VFT methodology. This section addresses step two through five of performing a VFT analysis: create value hierarchy, develop evaluation measures, create value functions, and weight the value hierarchy (Shovaik, 2001). Although there are ten steps to the VFT methodology, only the first five are addressed because the final five steps address the implementation of the model. Due to the large number of alternatives the VFT model would need to be applied to (over 130,000), the final five steps were beyond the scope of this research.

When creating a value hierarchy, the recurring themes identified by the Delphi were used. Specifically, the impact categories and performance measures identified in the first two rounds were used to produce weights in round III. Three out of four of the impact categories identified were 'ilities.' de Weck et al. (2012:1) defined 'ilities' as, "properties of engineering systems that often manifest and determine value… rather than being primary functional requirements, these properties concern wider system impacts." Revisiting the Federal Real Property Council's definition (2011) of MDI, there is no surprise that when inputs were defined a majority of them were 'ilities.' The first two rounds created a list of inputs that consisted of interruptability, redundancy, replaceability, and the number of missions affected. These inputs were assigned as impact categories for the hierarchy.

When defining interruptability, the same definition as the NAVFAC model was used, "how long could the 'functions' supported by your facility (functional element) be stopped without adverse impact to the mission?" (Antelman, Dempsey, & Brodt, 2008:142). This definition matched the themes addressed by the Delphi panel. The Delphi panel suggested this ‘iltiy’ must be addressed by the both the local leadership and the Core Function Lead Integrators (CFLI) to best represent its impact.

The next impact category identified was redundancy. The Delphi panel defined redundancy as, the availability of other assets to fulfill the same mission. This measure can be applicable to secondary runways or any other assets with backups. The panel suggested that this be examined at both the micro (local) level and macro (core function) level to truly capture the correct replaceability. Half of the panel agreed that redundancy of the assets should be taken into account at the micro (local) level, while the other half of the panel believed that redundancy should be applied at the macro (core function) level. In particular, the quality of life facilities were brought up when looking at the micro viewpoint as an opportunity to help alleviate some of the fiscal stress associated with the operations and maintenance of these facilities.

The third impact category identified was replaceability. The Delphi panel suggested that replaceability be measured as the time required to replace that asset or provide a work-around. This is important because if the asset can be repaired in a matter of hours, there is not as big of an impact to mission-capable level as when an asset may take months to repair.

The final impact category identified was the number of missions affected when an asset fails. This impact category addresses how interconnected an asset is to various mission sets. The panel felt that the number of missions at the local installation, as well as the core functions, must be addressed to characterize the asset’s interconnectivity at the micro and macro levels.

The impact categories and performance measures were developed in tandem. The impact categories are shown in the first level of the hierarchy in Figure 16. The second level of the hierarchy represents the performance measures identified by the Delphi study in round III. The performance measures were defined following the impact categories to ensure all of the impact categories were measurable after the panel agreed on them. Figure 16 represents the end of steps two and three of the VFT method used to create the value hierarchy and develop performance measures.

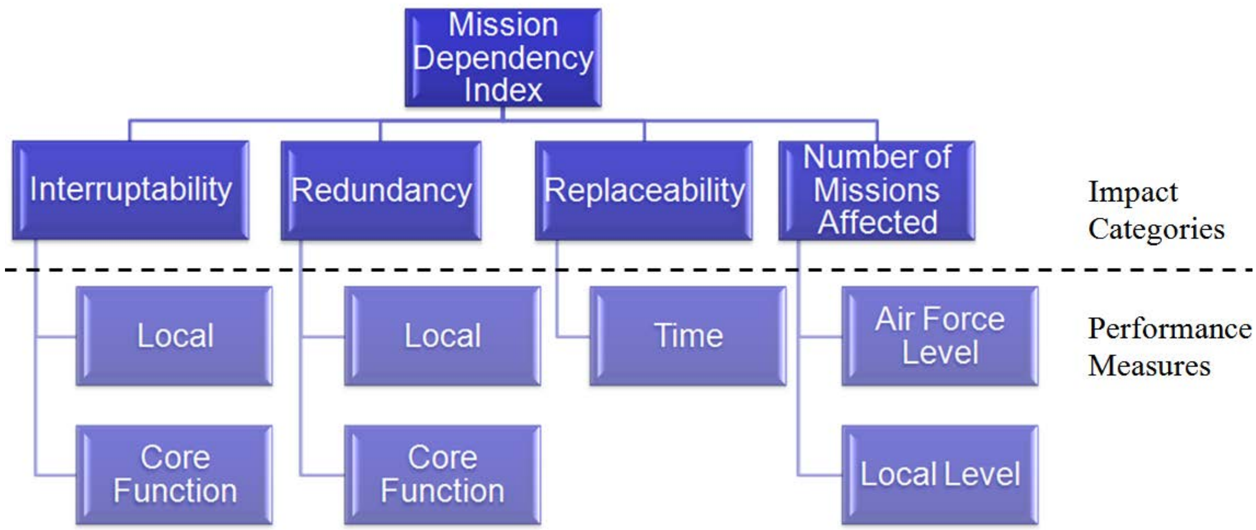


Figure 16. VFT MDI Hierarchy

After the performance measures were developed, the fourth step of creating value functions took place. Value functions "combine the multiple evaluation measures into a single measure of the overall value of each evaluation alternative" (Kirkwood, 1997:53). By creating value functions, the effect of how much each performance measure contributes to the overall scoring can be determined. Each value function was developed through feedback from the Delphi panel and adaptation from the literature review.

For the performance measures in the interruptability category, the NAVFAC scale was used to demonstrate how long the mission set could not be impacted with the asset's failure. This is a categorical scale with four categories (Antelman, Dempsey, & Brodt, 2008:142). The same scale was used for both the local and CFLI level decisions with the values of each category as shown in Figure 17. The values and definition for each level of the scale are:

- **Immediate (1.0)** (Any interruption will immediately impact mission readiness)
- **Brief (0.75)** (minutes or hours not to exceed 24 hours)
- **Short (0.5)** (Days not to exceed 7 days)
- **Prolonged (0.25)** (more than a week)

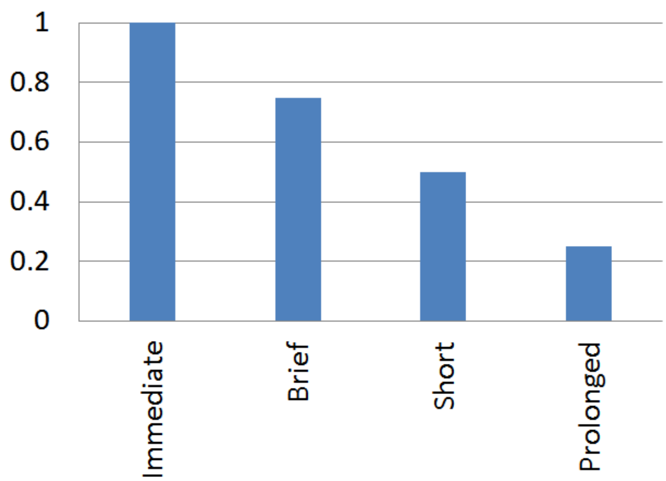


Figure 17. Value Function for Interruptability

Replaceability only contained one performance measure. The measure that was developed was the time required. In an effort to ease the use of the model for the Air Force CE career field, the same time scale as presented in the interruptability category was used. However, it must be noted that replaceability is measuring the time it would take to bring that asset back up to its capability. In addition, the points associated with the scale are reversed. The reversal happens because if the asset can immediately be replaced, it is not as imperative as an asset that will take more than a week to be replaced. Figure 18 shows the values used, and the definitions and points assigned are:

- **Immediate (0.25)** (Any interruption will immediately impact mission readiness)
- **Brief (0.5)** (minutes or hours not to exceed 24 hours)
- **Short (0.75)** (Days not to exceed 7 days)
- **Prolonged (1.0)** (more than a week)

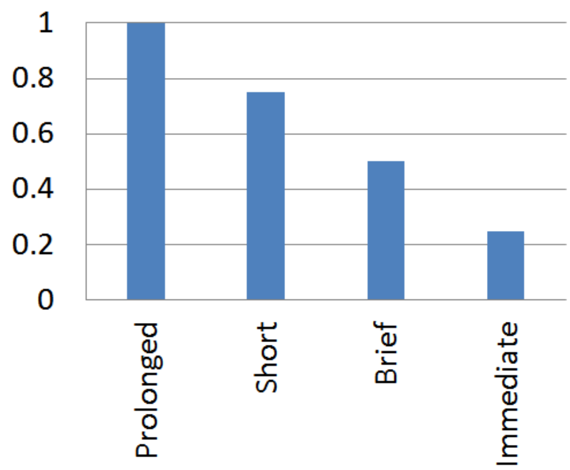


Figure 18. Value Function of Replaceability

The redundancy performance measures are addressed at both the local and core function level. The evaluation measure used for these performance measures was selected as a decreasing continuous function. Kirkwood (1997) recommends that if preferences decrease over the x-direction, then the appropriate value function is:

$$V(x) = \frac{1 - \exp\left[-\left(High - x\right)/\rho\right]}{1 - \exp\left[-\left(High - Low\right)/\rho\right]} \tag{4}$$

In this equation, ρ represents the exponential constant to shape the disutility curve. High and low are the minimum and maximum values of the range. The ρ value selected for this application was -5 to show the diminishing utility of having more redundant assets. This was modified from the value function titled “complexity of contingencies” by Karydas and Gifun (2006). The high and low values selected for were 5 and 0, respectively. The range was small because any asset that has more than 5 redundant partners is not as critical as a one-of-a-kind asset; therefore, the value in this performance measure is zero. At the CFLI level, this may result in many assets receiving 0 for the performance measure, but this helps identify one-of-a-kind assets in the Air Force. The weights associated with each integer in the value function were matched as closely as possible to the values identified by the Delphi panel. Figure 19 shows the value function and Table 4 shows the values resulting from the equation with the given assumptions.

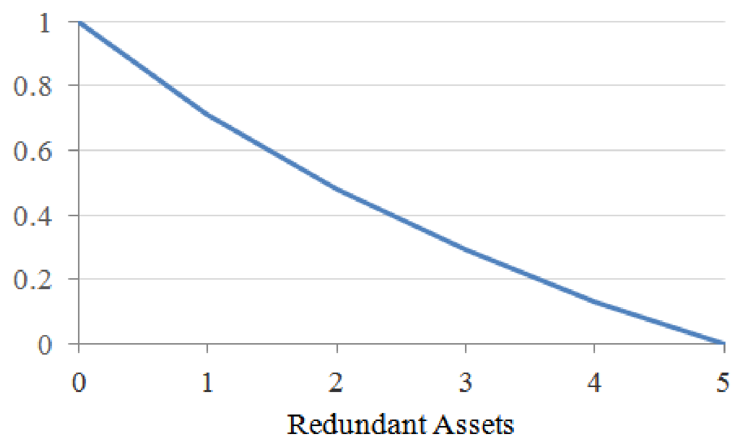


Figure 19. Value Function of Redundancy

Table 4. Redundant Assets Weights

Redundant Assets	Weight
0	1.00
1	0.71
2	0.48
3	0.29
4	0.13
5	0.00

The "number of missions affected" category also has two performance measures. Both the local and Air Force level mission sets were taken into account in this category. Adopting the law of diminishing returns applied by the NAVFAC model, these measures used an increasing preference evaluation measure with a ρ = 5 to show the overall impact. The minimum and maximum values were 0 and 10, respectively. The equation for increasing preferences is shown in equation 5 (Kirkwood, 1997). The resulting weights are shown in Figure 20 and Table 5.

$$V(x) = \frac{1 - \exp\left[-\left(x - Low\right)/\rho\right]}{1 - \exp\left[-\left(High - Low\right)/\rho\right]} \tag{5}$$

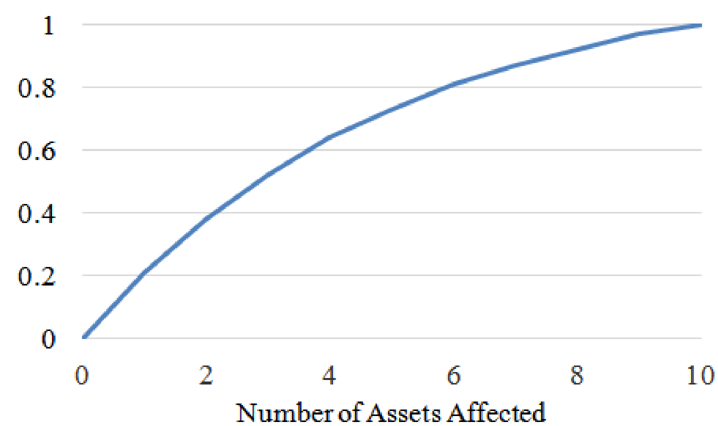


Figure 20. Value Function of Missions Affected

Table 5. Number of Mission Sets Affected Weights

# of Mission Sets Affected	Weight
0	0.00
1	0.21
2	0.38
3	0.52
4	0.64
5	0.73
6	0.81
7	0.87
8	0.92
9	0.97
10	1.00

With all of the performance measures defined and value scales developed, the fifth step of the VFT process is to give weights to the value hierarchy. During the final round of the Delphi, each panel member was asked to give weights to these categories. The panel members remained divided in the mindsets of micro (local) and macro (headquarters) viewpoints. Once the panel members were split into their respective group based off their open responses and weighting, each category (micro and macro) was averaged. One of the panel members only used 95 out of the possible 100 points for weights, so the response was standardized to a scale equal to the remainder of the responses. The average weights for each group are shown in Figure 21 and Figure 22.

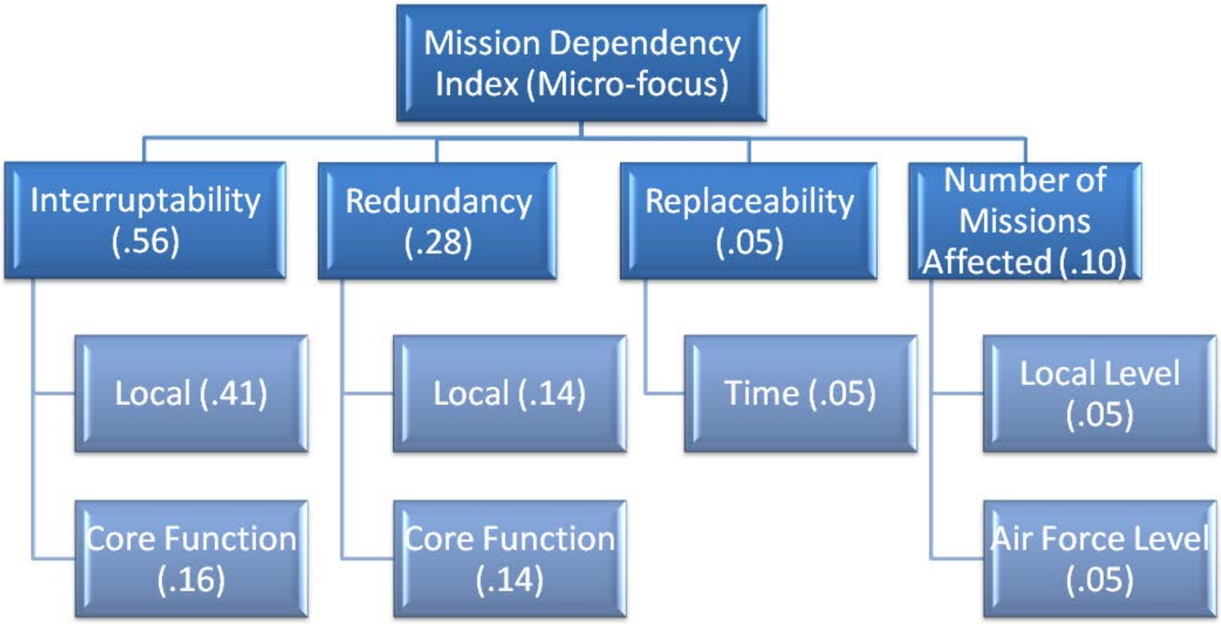


Figure 21. Micro Viewpoint VFT Hierarchy Weights

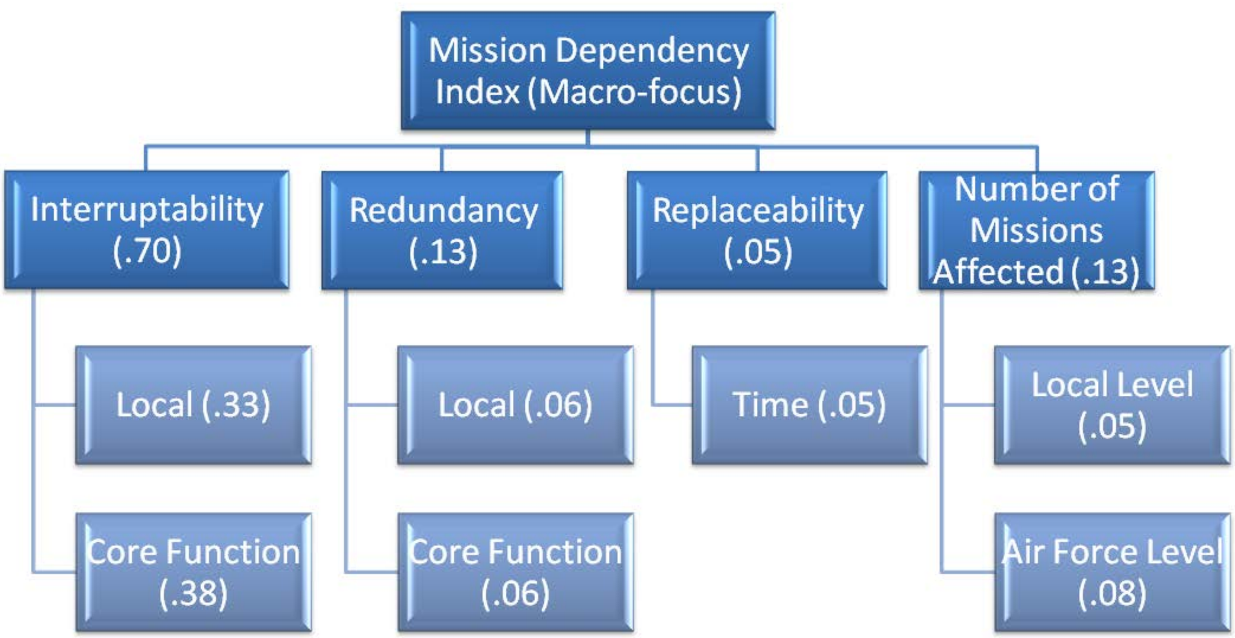


Figure 22. Macro Viewpoint VFT Hierarchy Weights

The resulting weights have the replaceability weight in common and the numbers of missions affected were very close. The installation-level point of view (micro view) yielded a model in which 60% of the MDI value comes from local decision-makers and 35% are managed at the CFLI level. The HAF point of view (macro view) resulted in a more balanced model, with the base accounting for 44% of the MDI value and HAF accounting for 51% of the model. These weights are shown in Figure 23 and Figure 24.

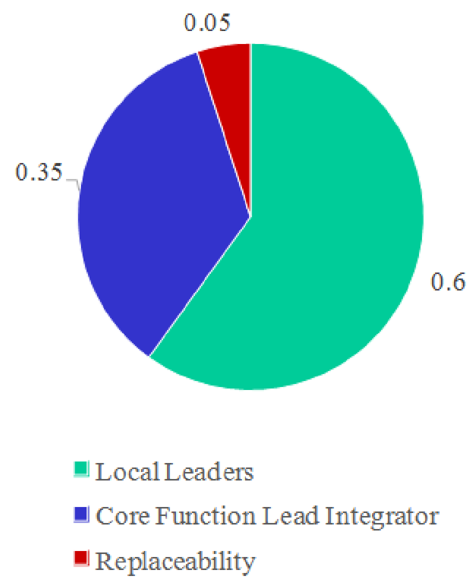


Figure 23. Micro Viewpoint Leadership Influence

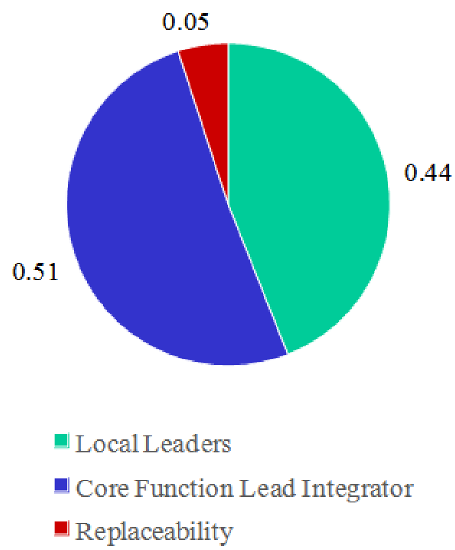


Figure 24. Macro Viewpoint Leadership Influence

In an effort to reduce bias toward the micro (local) and macro (headquarters) viewpoints, one additional model was created. This model used the feedback from all panel members with the exception of the one who was extremely biased toward the local level. The weights are the mean value assigned to each category by the panel. Because the micro and macro groups were equal, the final weights are averages and represent an attempt to reduce the groups' biases. The new hierarchy and weights are shown in Figure 25, and the combined leadership bias is shown in Figure 26.

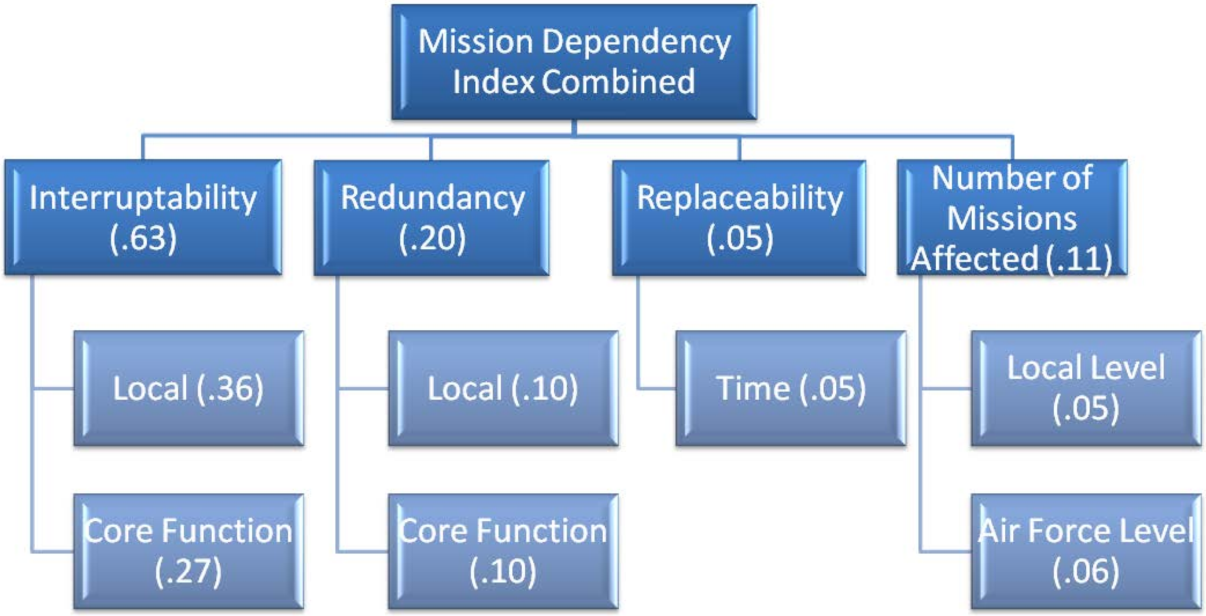


Figure 25. Combined Views Hierarchy Weights

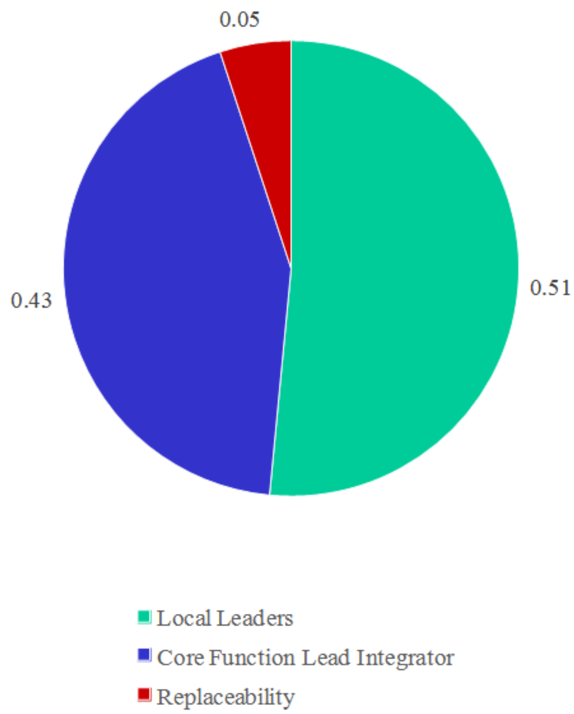


Figure 26. Combined Views Leadership Influence

One of the main benefits of the VFT methodology is that once the categories and measurements are defined, the weighting of the hierarchy and the performance measure scales can be adapted as leadership determines. The models developed in this chapter are meant to be applied at the individual asset level; however, the models could also be applied to the CATCODE level if the generalizations of assets that occur when using CATCODEs are accepted by the decision-makers. The following chapter will address the conclusions and recommendations of the research.

V. Conclusions and Recommendations

Throughout the Delphi study, the panel reaffirmed the importance of having a method to measure the consequence of failure of an asset. The questionnaire confirmed that currently the Air Force Civil Engineer (CE) community struggles with how to assign the Mission Dependency Index (MDI) values to assets. Despite this struggle, the data collected from the Delphi study and applied to the Value Focused Thinking (VFT) methodology produced three hierarchies to assist in assigning asset-specific MDI values. This section answers the investigative questions, addresses the study's conclusions, discusses the study's significance, and offers a few recommendations for future research.

Investigative Questions Answered

This section revisits the investigative questions and applies what was learned through the Delphi process. The first investigative question was, *what are the inputs needed to define the MDI value of a building?* The Delphi team identified the values associated with MDI to be interruptability, redundancy, replaceability, and the number of missions affected when a specific asset fails. These inputs should all be addressed when creating the MDI metric for an asset.

The second question was, *what weight should be applied to each of the inputs when assigning an MDI value to a facility or asset?* The study revealed a split in perspectives among the leaders interviewed. As a result of the divide, three models were produced: a micro (local) viewpoint, a macro (headquarters) viewpoint, and a model that combined the viewpoints. The weights were not agreed upon through the Delphi process due to time restrictions of the study. Resolving this disagreement is important to create a model that the entire CE career field can support and employ. Determining one set of weights for each input category and the performance measures is an area for possible future research. In addition to creating an agreed upon set of weights, the value functions that were adapted from the literature could be validated through leadership or by performing another questionnaire. Each value function can be adapted and changed to represent the decision-maker's desires.

The third question asked, *what is the desired distribution of the MDI values?* A portion of this question was answered in round I of the Delphi. The majority of the Delphi panel agreed that the range should be 0-100. The panel recognized that identifying the distribution of values is counter to the process, and the distribution should be validated after all alternatives have been applied to the model.

The final question investigated was, *according to CE subject matter experts (SME), how should the MDI be applied to the prioritization of infrastructure funding decisions?* All panel members agreed MDI values need to be included in the prioritization of funding decisions. When the metric is applied to prioritization, each situation needs to be focused on the requirement of the asset. The panel, regardless of their bias, identified that the importance to both the micro and macro levels needs to be taken into consideration. The bias of the members led to different weight being assigned to capture the influence of the two levels. In brief, each investigative question was addressed in the Delphi rounds in an effort to answer the research questions.

Conclusions and Significance of Research

As the Delphi study addressed each investigative question, the primary research question can be addressed: *how can the Air Force Civil Engineer Center (AFCEC) create a process to* *prevent MDI value inflation while maintaining a usable metric for funding decisions.* A review of the history of the current MDI definition created in 2008 revealed that it was meant as a stopgap measure until a more reasoned method was produced. Since 2008, efforts have been made by the CE career field to create internal processes to correct individual errors, but the underlying system issues remain. The biggest issue is that the current system has no way of calculating an MDI value of a building without comparing it to alternatives. This issue can be minimized if the impact categories and performance measures created by the CE leadership and SMEs in the Delphi process are taken into account. This research provides AFCEC with three models it can choose to implement, the micro perspective, the macro perspective, or the combined perspectives, to create asset-specific MDI values that do not require comparing it to alternatives throughout the Air Force.

The resulting values identified by the Delphi panel were similar to the Naval Facilities Engineering Command (NAVFAC) model. This is interesting because the NAVFAC model was not introduced to the panel until the last question of the final round. The values identified in the NAVFAC model were interruptability, relocateability, replaceability, and number of missions affected. The model produced in this research addresses all of those values except relocateability, as well as suggesting that a new value of redundancy should be incorporated. In the combined viewpoint model, redundancy accounted for 20 percent of the overall input when creating the MDI value. The NAVFAC model focused on the micro (local) level for 84% of the value and the micro viewpoint group in the panel suggested that local leaders should have 60% of the input into creating the MDI. These similarities of methodologies demonstrate that two different efforts created common values when creating a metric for the consequence of failure of infrastructure.

During this exploratory study, another effort was made by the CE career field to solidify the MDI metric. This demonstrates the recognition that the current system used to create MDI values needs to be more flexible for varying mission sets in addition to being more reproducible given the same constraints in two situations. This additional effort, accomplished by contract, involved representatives from every major command (MAJCOM), some base level experts, and individuals from AFCEC and headquarters Air Force. The effort identified the same issues as the Delphi team. The contract effort created another method to adjust individual category codes (CATCODE) MDI values; however, it only fueled the inflation issue since it did not include the redistribution of values when an individual is granted a higher MDI value.

Recommendations for Action and Future Research

Using the data and analysis gathered from this research, additional research could be pursued to further explore the issues for which the Delphi team could not reach a consensus over. The first area that could be examined is finding a balance between the micro (local) level perspective and macro (higher headquarters) level perspective. The second area could use the existing values and evaluate the system using the analytical network processing (ANP) method outlined by Cheng and Li (2005). Cheng and Li's process involves creating a network model that uses qualitative and quantitative data to create decision possibilities based on user-defined objective functions. Leveraging qualitative data collected in 2008 using the NAVFAC methodology at two bases, the ANP method could be applied to see if the models recommended in this research reflect leadership's desires. Another recommended area for additional research would be to examine how the MDI could be applied in an expeditionary setting that becomes more permanent. Recently, the presence in the Middle East has reduced, but the Air Force desires to maintain a number of bases in a more permanent posture. As the infrastructure changes from expeditionary to permanent, the funding methods may change as well. The final recommendation is to acquire the required data from an existing installation and apply the model presented with the two varying weights to see how the model performs and how it can be adapted to accurately capture real-world conditions.

Summary

This research began as an effort to correct the MDI system the Air Force employs and identify the inputs that should be taken into consideration. During the process of identifying the inputs, other areas for improvement outside the scope of this study were revealed. Despite the inability to converge on what level the MDI represents, micro or macro, two models were created in an effort to show each perspective. Overall, using this research, the CE career field can improve the current methodology and, more importantly, continue to improve the MDI effectiveness in the prioritization of projects for funding.

Appendix A. NAVFAC Survey Questions

(Antelman, Dempsey, & Brodt, 2008)

Question #1: How long could the "functions" supported by your facility *(functional element)* be stopped without adverse impact to the mission?

- **Immediate** *(any interruption will immediately impact mission readiness),*
- **Brief** *(minutes or hours not to exceed 24 hours),*
- **Short** *(days not to exceed 7 days),* or
- **Prolonged** *(more than a week).*

Question #2: If your facility was no longer functional, could you continue performing your mission by using another facility, or by setting up temporary facilities? (Are there workarounds?)

- **Impossible** *(an alternate location is not available),*
- **Extremely Difficult** *(an alternate location exists with minimally acceptable capabilities, but would require either a significant effort (money/man-hours), dislocation of another major occupant, or contracting for additional services and/or facilities to complete),*
- **Difficult** *(an alternate location exists with acceptable capabilities and capacity but relocation would require a measurable level of effort (money/man-hours), but mission readiness capabilities would not be compromised in the process),*
- **Possible** (*an alternate location is readily available with sufficient capabilities and capacity, in addition the level of effort has been budgeted for or can be easily absorbed).*

Question #3: How long could the services provided by *(named organizational subcomponent)* be interrupted before impacting your mission readiness?

- **Immediate** *(any interruption will immediately impact mission readiness),*

- **Brief** *(minutes or hours not to exceed 24),*
- **Short** *(days not to exceed 7 days),* or
- **Prolonged** *(more than a week or there are more than sufficient redundancies or there is a known quantity of excess capacity available in the foreseeable future).*

Question #4: How difficult would it be to replace or replicate the services provided by *(named organizational subcomponent)* with another provider from any source before impacting the command's mission readiness?

- **Impossible** *(there are no known redundancies or excess/surge capacities available, or there are no viable commercial alternatives,*
- **Extremely Difficult** *(there are minimally acceptable redundancies or excess/surge capacities available, or there are viable commercial alternatives, but no readily available contract mechanism in place to replace the services),*
- **Difficult** (*services exist and are available, but the form of delivery is ill defined or will require a measurable and unbudgeted level of effort to obtain (money/man-hours), but mission readiness capabilities would not be compromised in the process),*
- **Possible** (*services exist, are available, and are well defined*).

Appendix B. MIT Impact Categories and Performance Measure Definitions

(Karydas & Gifun, 2006:89)

Definitions, impact categories and performance measures

Complexity of contingencies	Minimize the cost of contingency arrangements necessary for the continuity of academic activities and operations of the institute. Performance measure: The monetary cost of contingency arrangements necessary to ascertain the continuity of academic activities and operations for the restoration period.
Coordination with policies, programs, and operations	Consider the degree of association of the proposed project with the academic (teaching and research) and business objectives of the Institute and minimize the impact that its delayed completion may have in terms of public image, academic program budgets and number of students involved and employed in the associated program
Economic impact of the project	Evaluate the proposed project considering the economic impact that a delayed completion may have in terms of the physical damage of real and intellectual property, disruption of continuity of institute operations and wasted moneys representing added costs of condition-induced deterioration and lack of modernization-induced efficiencies.
External public image	Minimize the impact of (a) the delayed completion of the project and (b) events associated with this delay on the image of the Institute held by parents of prospective students, prospective students, granting agencies, donors, and regulatory agencies. Performance measure: degree of the negative image held by parents of prospective students, prospective students, granting agencies, donors, and regulatory agencies.
Impact on the environment	Minimize the impact on the environment from hazards associated with deficiencies that will be corrected with the proposed project. Performance measure: The severity of environmental damage caused by events associated with delayed completion of the proposed project. Impact on the environment, applies to the environment outside of campus buildings and impacts that could occur in the utility systems beyond the projection of the exterior façade of any buildings.
Impact on health, safety, and the environment	Evaluate proposed project considering risk reduction opportunities introduced by the project's completion. Minimize risk to people and the environment by correcting deficiencies associated with the proposed project.
Impact on people	Minimize the impact on students, faculty and the public from perils associated with deficiencies that will be corrected with the proposed project. Performance measure: death, injury, and illness on individuals affected by the delayed completion of the proposed project.
Impact on property, academic, and institute operations	Minimize the impact on property (buildings and equipment and intellectual property) from damage associated with the delayed completion of the proposed project. Minimize business interruption caused by events associated with the delayed completion of the proposed project, i.e. ascertain the continuity of academic activities (teaching and research) by making appropriate contingency arrangements.
Impact on public image	Minimize the impact on the positive image that the institute strives to maintain toward the community, parents, business partners, sponsors, regulatory agencies, and local government.
Intellectual property damage	Minimize the impact on intellectual and intangible property from damage associated with the delayed completion of the proposed project. Performance measure: degree of 'replaceability' of affected property associated with the delayed completion of the proposed project.
Internal public image	Minimize the impact of (a) the delayed completion of the project and (b) events associated with this delay on the image of the Institute held by parents of existing students, students, faculty, staff, and other members of the MIT community. Performance measure: degree of the negative image held by parents of existing students, students, faculty, staff, and other members of the MIT community.
Interruption of academic activities and operations	Minimize the impact on the continuity of academic activities (teaching, research, and other supporting activities, such as work environment or living accommodations) where appropriate contingency arrangements are necessary for the period necessary to restore normal operations.
Interruption time	Minimize the length of interruption time of academic activities and other institute operations. Performance measure: the length of time needed to restore academic activities and operations.
Loss of cost savings	Minimize the loss of cost savings associated with the delayed completion of the project until unacceptable deterioration or damage occurs or excessive additional cost is involved. Also, consider possible lost cost savings, which otherwise might be obtained with the introduction of new technologies, higher efficiency, and innovative design associated with the proposed project. Performance measure: the amount of savings, as the difference between the current cost and the cost associated with the delayed completion of the proposed project (when irreversible damage may occur). Also the additional amount of savings associated with the implementation of new technologies or efficient design.
Physical property damage	Minimize impact on property (land, buildings, and equipment) from damage associated with the delayed completion of the proposed project. Performance measure: cost of restoration of affected property associated with the delayed completion of the proposed project.
Programs affected by the project	Minimize the impact on academic program budgets, the number of students involved and employed in the associated program and the institute's business objectives associated with the delayed completion of the proposed project. Performance measures: budget amount of academic program or operation, the number of affected students, or both.

Appendix C. VFT Description

A Proposed Value Focused Thinking Study for:
Mission Dependency Index Metric

Primary Researcher: Captain Matthew Nichols
United States Air Force, Air Force Institute of Technology

VALUE FOCUSED THINKING STUDY GOALS

The purpose of this Value Focused Thinking (VFT) study is to provide Air Force Civil Engineer Center (AFCEC) with a method to create and apply the Mission Dependency Index (MDI) metric currently used in the prioritization of United States Air Force Civil Engineer (CE) projects while preventing inflation of the values.

This study will address the following questions:
What inputs are taken into consideration when determining an MDI value?
What is the desired distribution of the MDI values to ensure the appropriate application of the metric?
How should the MDI be obtained/assigned to a facility?

VALUE FOCUSED THINKING BACKGROUND AND COMPOSITION

MDI Value Information
The MDI values currently assigned to buildings where assigned because of the Categorization Code (CATCODE). NAVFAC provided CE with the data produced through their survey methodology and the data was adapted to the Air Force's infrastructure. During this adaptation, the conservative values for each CATCODE were taken to mitigate any risk. Over the life of the metric, the MDI values of specific CATCODES have been adjusted by MAJCOMs and AFCEC. This course of action has lead to an inflation issue with MDI values.

Value Focused Thinking Background
A VFT study is a methodology used for gathering data about topics of processes to generate a model that ties strategic goals to routine operations. VFT pre-establishes the different input values applied in organizational decision-making instead of Alternative focused thinking, the process of selecting the strongest alternative. The study is conducted by selecting a panel of experts in a specific field and engaging them in a guided, anonymous discussion by asking the group specific, pointed questions. Through multiple rounds of questions, expert opinions are gathered and discussed amongst the group in an effort to garner consensus and/or highlight differences in opinions on the topic of discussion. Throughout the iterative process, a model is created to identify and maximize decision opportunities.

Panel Composition

The desired panel will be composed of 10 – 20 individuals. The target group of members should be subject matter experts or senior leaders in the CE career field. This combined group will create an overall panel capable of generating a clearly defined MDI metric for use in the prioritization model.

Air Force Civil Engineer Senior Leader Expertise
This group of experts will consist of 5-10 individuals each of whom should meet the following qualifications:
Minimum 15 year of experience managing infrastructure assets
Working knowledge of the CE Prioritization model

Air Force Civil Engineer Subject Matter Expert Expertise
This group of experts will consist of 5-10 individuals each of whom should meet the following qualifications:
Minimum 3 years of experience prioritizing infrastructure asset projects
Working knowledge of the CE Prioritization model
Specific knowledge of CE funding and prioritization actions in support of public infrastructure

Participation Requirements for All Panel Members
The panel will be conducted <u>electronically via email</u>. This will afford panel members flexibility and anonymity in participation. All panel participants will be requested to participate in the study by providing the following input:
A brief demographic questionnaire before the study begins
Minor additional input as requested for study approval by the Institution Review Board
2 - 4 rounds of discussion. Each round will consist of:
A brief list of multiple choice questions
Several open ended questions and/or an open comments section
Results and input from all participants for the previous round (except first round)
Each round is anticipated to require <u>no more than 20 minutes</u> of participant time
Optional: review of final round conclusions

NOTIONAL VALUE FOCUSED THINKING SCHEDULE

This study is expected to run from 1 September 2014 through 31 December 2014. A notional timeline for the study is presented in Table 1. The **bold** items in Table 1 indicate items which will require panel member participation.

Table 1. Notional Schedule

Scheduled Item	**Date (2014)**
Installation Review Board (IRB) approval process	1 - 22 September
Draft Value Focused Thinking questions for Round 1	1 - 22 September
Select panel members	25-29 September
Solicit panel member demographic information	**25-29 September**
Round 1	**1 - 8 October**
Compile Round 1 responses, draft Round 2 questions	8 October - 15 October
Round 2	**15 - 29 October**
Compile Round 2 responses, draft Round 3 questions	29 October - 6 November
Round 3	**6 November - 20 November**
Compile Round 3 responses, draft final conclusions	20 - 27 November
Distribute final conclusions to participants	6 December

CONTACT INFORMATION

Should any questions arise about the study or its goals or execution, please contact the primary researcher directly at any of the following:

Matthew Nichols
Captain, United States Air Force
Student, Air Force Institute of Technology
matthew.nichols@afit.edu or nichols.matthew.j@gmail.com
(303) 895-5580

Appendix D. Round I Delphi Questions

Mission Dependency Index Metric:
A Value Focused Thinking Study
Primary Researcher: Captain Matthew Nichols
United States Air Force, Air Force Institute of Technology
Questions for Round One of the Value Focused Thinking Study

1) What does the Mission Dependency Index (MDI) Value represent in an infrastructure portfolio?

   Please provide a definition in your own words.

2) What are the strengths of using current MDI values?

3) What are the weaknesses of using the current MDI values?

4) What inputs need to be taken into consideration when determining the MDI value of a facility? Please provide at least three inputs.

   1.
   2.
   3.

5) What are the advantages and disadvantages to the MDI value being asset specific?

   Advantages:

   Disadvantages:

6) What are the advantages and disadvantages to the MDI value be dependent on groups such as CATCODEs?

   Advantages:

   Disadvantages:

7) Would grouping individual assets to a bundle within individual assigned CATCODEs be appropriate?

8) What is the desired distribution of the MDI values?

9) At what level should the MDI values be consistent?

10) Is there another metric the CE Career field should use rather than MDI to assist in the prioritization of projects?

Appendix E. Round I Delphi Coding and Combined Answers

1) What does the Mission Dependency Index (MDI) Value represent in an infrastructure portfolio?

Theme
Criticality
AF Mission
Local Mission
Consequence of Failure
Importance

2) What are the strengths of using current MDI values?

Theme
Consistent
Easy to use
Objective
Repeatable
Common frame of reference
Assists in prioritization

3) What are the weaknesses of using the current MDI values?

Theme
Non-Flightline missions not identified/not objective
CATCODEs/lack of individuality
No local mission impact
No account of redundancy
Does not account for 2nd/3rd/4th order effects/whose mission?

4) What inputs need to be taken into consideration when determining the MDI value of a facility? Please provide at least three inputs.

Theme
AF Mission/DOD/COCOM
Local Mission/asset specific
Redundancy
Replaceability
Life/health/safety

Current system
Facility type/usage

5) What are the advantages and disadvantages to the MDI value being asset specific?

Advantages:

Theme
Relative mission impact
Adaptability
More adaptable to non-standard mission sets

Disadvantages:

Theme
Not reflecting the AF mission
Inflation of values/non mission QOL bldgs getting high MDIs
Expensive/time and money
Do not know

6) What are the advantages and disadvantages to the MDI value be dependent on groups such as CATCODEs?

Advantages:

Theme
Easy/repeatable
Standardized across the AF/reputable
Good starting point

Disadvantages:

Theme
No tie to local mission/specific Asset
Bad data

7) Would grouping individual assets to a bundle within individual assigned CATCODEs be appropriate?

Green is the majority, yellow is half, red is the minority

Theme
Yes
No
Maybe

System approach

8) What is the desired distribution of the MDI values?

Theme	
Normal	40-100
0-100	Do not apply one
50-100	Did not understand

9) At what level should the MDI values be consistent?

Theme

AF

MAJCOM

BASE

Mission

none

Did not understand

10) Is there another metric the CE Career field should use rather than MDI to assist in the prioritization of projects?

Theme

No

PAL

Local Mission/asset specific

FUB

CSAF Priorities

Appendix F. Round II Delphi Questions

Mission Dependency Index Metric:
A Value Focused Thinking Study
Primary Researcher: Captain Matthew Nichols
United States Air Force, Air Force Institute of Technology
Questions Round Two of the Value Focused Thinking Study

1) The common themes identified by the panel for the Mission Dependency Index (MDI) definition are shown below. Please circle or highlight whether you agree or disagree with the inputs.

Criticality to		
Local Mission		Agree Disagree
Air Force Mission	Agree	Disagree
Consequence of Failure	Agree	Disagree
Measurement of mission completion using that specific asset	Agree	Disagree

Open Response:

2) When addressing the weaknesses of the current MDI, the panel noted that current MDI values do not account for redundant assets. How should redundancy be accounted for?

Open Response:

3) Another weakness identified by the panel in Round 1 is that the current system does account for the replaceability of an asset. To address this issue, should a monetary, mission impact, or another metric be used in determining the MDI value?

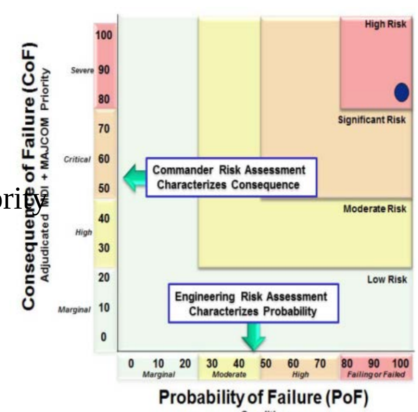
Monetary   Mission Impact   Other:_______________

Open Response:

4) Currently, the MDI is applied with the MAJCOM Priority to determine the Consequence of Failure (CoF) metric for the SRM funding model. (MDI is 60% and the MAJCOM Priority is 40%)

i. Does the MAJCOM priority adequately account for the local mission?
Yes   No

ii. Over time, should the weights applied to MAJCOM priority and MDI be adjusted?
Yes   No



iii. If yes, what percentage should each portion be to determine the CoF metric?

MAJCOM Priority ____________ MDI Value ________________

Does the current adjudication process lead to these metrics combining? (please see the end of the document for more information on the adjudication process)

Open Response:

5) Every agency/organization has a mission. At what level should the mission effect applied to MDI be distinguished: the Air Force, MAJCOM, or Wing level?

6) Should each mission set or Core Function have an adjustment factor to vary the MDI value assigned to the CATCODEs associated with their primary mission? (ex. AETC's classrooms would be adjusted to be higher than other MAJCOMs, please see the end of the survey for the Core Functions list)

Yes No

Open Response:

7) In round 1, the panel was suggested that the prioritization happens at the base level through the use of the Integrated Priority List (IPL). Should there be a portion of the CoF that originates from the IPL?

Yes No

i. If yes, please elaborate on how the MDI metric could maintain consistency at the prescribed level (AF, MAJCOM , or Wing) through this process.

Open Response:

8) One team member stated, "Since the installations are not involved in the process, there is no buy-in for how that number (MDI) is created." What are possible courses of action to fix this?

Open Response:

9) One team member pointed out that the MDI is used for funding decisions. Because of this, the career field is now applying an asset importance metric to projects (that may impact more than one asset).

i. When this is the case, which MDI should be applied?

Open Response:

ii. Another team member pointed out that many functions are often consolidated into one asset. Should there be a modification to the current MDI model so that different MDIs could be applied to different functional areas of the asset?

Open Response:

	Core Function Lead Integrators (in green) & OCRs (indicated by checkmarks)											HAF
	ACC	AETC	AFGSC	AFMC	AFRC	AFSOC	AFSPC	AMC	NGB	PACAF	USAFE	
Nuclear Deterrence Ops	✓	✓	AFGSC/ CC	✓	✓	✓	✓	✓	✓	✓	✓	A10
Air Superiority	ACC/CC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A3/5
Space Superiority	✓	✓	✓	✓	✓	✓	AFSPC/ CC	✓	✓	✓	✓	A3/5
Cyberspace Superiority	✓	✓	✓	✓	✓	✓	AFSPC/ CC	✓	✓	✓	✓	A3/5, A6
Global Precision Attack	ACC/CC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A3/5
Rapid Global Mobility	✓	✓	✓	✓	✓	✓	✓	AMC/CC	✓	✓	✓	A3/5
Special Operations	✓	✓	✓	✓	✓	AFSOC/ CC	✓	✓	✓	✓	✓	A3/5
Global Integrated ISR	ACC/CC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A2
Command and Control	ACC/CC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A2, A3/5, A4/7, A6
Personnel Recovery	ACC/CC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A3/5
Building Partnerships	✓	AETC/CC	✓	✓	✓	✓	✓	✓	✓	✓	✓	IA
Agile Combat Support	✓	✓	✓	AFMC/CC	✓	✓	✓	✓	✓	✓	✓	AQ, A1, A3/5, A4/7

The current adjudication process allows for MAJCOMs to suggest a change in the MDI value assigned to specific CATCODEs. The entire process is outlined in the CoF playbook below.

Appendix G. Round II Delphi Coding and Combined Answers

1) The common themes identified by the panel for the Mission Dependency Index (MDI) definition are shown below.

Local Mission	Agree:5	Disagree:1	
Air Force Mission	Agree:5	Disagree:1	
Consequence of Failure	Agree:6	Disagree:0	
Measurement of mission completion using that specific asset	Agree:3	Disagree:1	Neither: 2

2) When addressing the weaknesses of the current MDI, the panel noted that current MDI values do not account for redundant assets. How should redundancy be accounted for?

Theme
Money
Time
Local Redundancy
AF Wide Redundancy
With a CFLI Coefficient
Mission Capacity

3) Another weakness identified by the panel in Round 1 is that the current system does account for the replaceability of an asset. To address this issue, should a monetary, mission impact, or another metric be used in determining the MDI value?

Theme
Money
Mission
Impact
Time

4) Currently, the MDI is applied with the MAJCOM Priority to determine the Consequence of Failure (CoF) metric for the SRM funding model. (MDI is 60% and the MAJCOM Priority is 40%)

a. Does the MAJCOM priority adequately account for the local mission?
Yes No

b. Over time, should the weights applied to MAJCOM priority and MDI be adjusted?
Yes No

c. If yes, what percentage should each portion be to determine the CoF metric? Two groups

MAJCOM Priority	MDI Value
TBD	TBD
0	100

Does the current adjudication process lead to these metrics combining? Yes

Theme
Local
MAJCOM
HAF
Commander Influence

5) Every agency/organization has a mission. At what level should the mission effect applied to MDI be distinguished: the Air Force, MAJCOM, or Wing level?
Two Groups

Theme
AF
Wing

6) Should each mission set or Core Function have an adjustment factor to vary the MDI value assigned to the CATCODEs associated with their primary mission? (ex. AETC's classrooms would be adjusted to be higher than other MAJCOMs, please see the end of the survey for the Core Functions list)

Yes No

7) In round 1, the panel was suggested that the prioritization happens at the base level through the use of the Integrated Priority List (IPL). Should there be a portion of the CoF that originates from the IPL?

Yes No

a. If yes, please elaborate on how the MDI metric could maintain consistency at the prescribed level (AF, MAJCOM , or Wing) through this process.

N/A

8) One team member stated, "Since the installations are not involved in the process, there is no buy-in for how that number (MDI) is created." What are possible courses of action to fix this?

Theme
Adjudication process
Involve local leadership in development of value
Have each MAJCOM articulate issues

9) One team member pointed out that the MDI is used for funding decisions. Because of this, the career field is now applying an asset importance metric to projects (that may impact more than one asset).
   a. When this is the case, which MDI should be applied?

   b. Another team member pointed out that many functions are often consolidated into one asset. Should there be a modification to the current MDI model so that different MDIs could be applied to different functional areas of the asset?

Evenly split throughout themes

Theme
Weighted average
Highest Value
Requirement specific

Appendix H. Round III Delphi Questions

Mission Dependency Index Metric:
A Value Focused Thinking Study
Primary Researcher: Captain Matthew Nichols
United States Air Force, Air Force Institute of Technology
Questions Round Three of the Value Focused Thinking Study

1) Throughout the last two rounds, the panel has identified the following inputs that MDI should address; please place the weights you believe each section should have. All of the weights should sum to equal 100.

   Criticality to the local mission (Wing): _______
   Criticality to the AF/MAJCOM Mission (Core Function): _______
   Redundancy: _______
   Time to replace: _______
   Cost: _______
   Number of local missions impacted: _______
   Number of Core Functions impacted: _______

   Open Response:

2) One member stated, "We are trying to make a system which circumvents commander influence; I believe their job is to influence." Other members of the panel believed the Consequence of Failure (CoF) metric should have the MAJCOM priority removed with just the MDI remaining. After accomplishing this task, the MAJCOM priority points should be applied separately from the CoF and Probability of Failure (PoF) graph. This method may be able to reduce the fair share and "gaming" the system that currently happens.

   Do you agree with this methodology or is there another possible route to take?
   Open Response:

3) Another member brought up, "Should services that are available in the surrounding community be taken into consideration when looking at the redundancy of an asset?" If the service provided by the facility can be absorbed by the community in the event of asset failure should this be addressed when establishing the MDI value?

   Yes: No:
   Open Response:

4) One panel member pointed out, the Navy's methodology works for them and addresses most of the issues the Air Force's process has.

NAVFAC sends a team out that asks local commanders about local impacts as well and the impacts of others for each asset and then normalizes the MDI values using an equation that is 84% intra-dependency, 11% inter-dependency and 5% the number of leaders that believe the asset is important. (full methodology available in the PDF at the end of the document)

Would you as an expert, suggest for the Air Force to fund a team to establish MDI values using the Navy methodology?

Yes: No:

Open Response:

5) Any suggestions for future research areas for AFIT of AFCEC?

Appendix I. Round III Delphi Coding and Combined Answers

1) Throughout the last two rounds, the panel has identified the following inputs that MDI should address; please place the weights you believe each section should have. All of the weights should sum to equal 100.

	Panel Member				
Values for the MDI Metric	A	B	C	D	E
Criticality at the Local level	30	40	50	90	25
Criticality of the Core Functions (AF level)	20	40	10	5	35
Redundancy	35	10	20	5	15
Time to replace	10	10	0	0	0
Cost	0	0	0	0	0
Number of Local Level Missions Impacted	0	0	10	0	10
Number of Core Functions Missions Impacted (AF level)	0	0	10	0	15

2) One member stated, "We are trying to make a system which circumvents commander influence; I believe their job is to influence." Other members of the panel believed the Consequence of Failure (CoF) metric should have the MAJCOM priority removed with just the MDI remaining. After accomplishing this task, the MAJCOM priority points should be applied separately from the CoF and Probability of Failure (PoF) graph. This method may be able to reduce the fair share and "gaming" the system that currently happens. Do you agree with this methodology or is there another possible route to take?

2 groups

Theme

Minimize local Commander's influence

Maximize local Commander's influence

3) Another member brought up, "Should services that are available in the surrounding community be taken into consideration when looking at the redundancy of an asset?" If the service provided by the facility can be absorbed by the community in the event of asset failure should this be addressed when establishing the MDI value?

Yes: Half　　　　No : Half

4) One panel member pointed out, the Navy's methodology works for them and addresses most of the issues the Air Force's process has.

NAVFAC sends a team out that asks local commanders about local impacts as well and the impacts of others for each asset and then normalizes the MDI values using an equation that is 84% intra-dependency, 11% inter-dependency and 5% the number of leaders that believe the asset is important. (full methodology available in the PDF at the end of the document)

Would you as an expert, suggest for the Air Force to fund a team to establish MDI values using the Navy methodology?

Yes: Half No: Half

Appendix J. AFCEC Sponsor Letter to Delphi Participants

DEPARTMENT OF THE AIR FORCE
AIR EDUCATION AND TRAINING COMMAND

6 October 2014

MEMORANDUM FOR VALUE FOCUSED THINKING STUDY MEMBERS

FROM: Lieutenant Colonel Chad B. BonDurant, AFCEC/CPAD

SUBJECT: Significance of Value Focused Thinking (VFT) Study on Mission Dependency Index (MDI) Values

1. The Air Force Civil Engineer Center (AFCEC) is sponsoring an Air Force Institute of Technology (AFIT) thesis effort to better define the Mission Dependency Index (MDI) value distribution, definition, and adaptability. The MDI is generated automatically based on CATCODE. The current business rules allow MAJCOMs to submit an MDI adjustment request for specific facilities if unique circumstances exist. However, AFCEC is concerned this may cause MDI values to inflate over time reducing their decision making value. This research is an effort to help identify a systematic and transparent approach to keep MDI values in the desired distribution.

2. This VFT study seeks to determine what value senior asset managers and leaders believe the MDI metric provides. The MDI values are currently assessed from an Alternative-Focused Thinking (AFT) mindset. The AFT framework looks at all identified alternatives and ranks the options from that point of view. However, one major flaw with the AFT style of decision-making is that if the alternative is not identified, it cannot compete, or one alternative is overemphasized.

3. The VFT approach identifies the overarching goals of a metric and uses those metrics to establish a model. This approach is beneficial because it creates a repeatable process that can be applied to any alternative, even those identified later. Any alternatives evaluated with this model will then be consistent with the corporate goals identified through this research effort.

4. The current MDI was produced by adapting NAVFAC facility data for use with USAF facilities. This research stream is not designed to overhaul the current MDI system. It is designed to provide a more defendable scoring model for the centralized program. This research in combination with the recently developed playbook will enhance the USAF MDI values reliability.

5. If you have any questions or concerns about this study please feel free to contact the action officer, Captain Matt Nichols at 303-895-5580 or matthew.nichols@afit.edu.

CHAD B. BONDURANT, Lt Col, USAF
Chief, Comprehensive Program Development Branch
Air Force Civil Engineer Center

Appendix K. AFIT Human Subjects Exemption Approval

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OHIO

22 Sept 2014

MEMORANDUM FOR DR. AL THAL

FROM: Jeffrey A. Ogden, Ph.D.
AFIT IRB Research Reviewer
2950 Hobson Way
Wright-Patterson AFB, OH 45433-7765

SUBJECT: Approval for exemption request from human experimentation requirements (32 CFR 219, DoDD 3216.2 and AFI 40-402) for the Mission Dependency Index Value Focused Thinking Model

1. Your request was based on the Code of Federal Regulations, title 32, part 219, section 101, paragraph (b) (2) Research activities that involve the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior unless: (i) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) Any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

2. Your study qualifies for this exemption because you are not collecting and reporting sensitive data, which could reasonably damage the subjects' financial standing, employability, or reputation. Further, you are not collecting and reporting any demographic data which could realistically be expected to map a given response to a specific subject.

3. This determination pertains only to the Federal, Department of Defense, and Air Force regulations that govern the use of human subjects in research. Further, if a subject's future response reasonably places them at risk of criminal or civil liability or is damaging to their financial standing, employability, or reputation, you are required to file an adverse event report with this office immediately.

9/22/2014

X Jeffrey A. Ogden

Jeffrey A. Ogden, Ph.D.
IRB Exempt Determination Official

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Vita

Captain Matthew J. Nichols graduated from Colorado School of Mines with a Bachelor of Science degree in Engineering in December of 2009. He was commissioned as a Second Lieutenant in the U.S. Air Force through AFROTC Detachment 105 at the University of Colorado. He was first assigned to the 341st Civil Engineer Squadron, Malmstrom Air Force Base (MAFB), Montana. While at MAFB, Capt Nichols served in various roles. He was in the Programs Flight as a design engineer and project manager in the civil engineering section, the Chief of Asset Optimization, the Chief of Operations support and the Operations Flight Commander. In August 2013, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. His next assignment will be at Kunsan AB, Korea.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 074-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
26-03-2015	Master's Thesis	03 Sept 2013 - 26 Mar 2015

4. TITLE AND SUBTITLE	
A DELPHI STUDY USING VALUE-FOCUSED THINKING FOR UNITED STATES AIR FORCE MISSION DEPENDENCY INDEX VALUES	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER** N/A
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14. ABSTRACT
Recently, the Air Force Civil Engineer Center (AFCEC) identified that the Mission Dependency Index (MDI) had issues with reflecting the criticality of some mission sets. The MDI is a constructed value assigned to assets that reflects the consequence of failure. The primary mission sets having MDI issues were non-flightline assets. The current Air Force MDI metric relies on data collected using the Naval Facilities Engineering Command (NAVFAC) methodology and adapts the data by using facility categorization codes. The result is a method that compares alternatives to each other to develop an individual asset's MDI value. As a corrective measure to this methodology, non-flightline centric mission sets have been allowed to adjust (i.e. increase) their asset MDI values. This modification in MDI values has led to inflation of the metric.
To address the issue, this research focuses on how the MDI values should be assigned by examining both public and private methodologies. Leveraging the Delphi technique and Value Focused Thinking (VFT), three models are created to suggest the proper inputs that should be considered when producing the MDI values for the Air Force's assets. The models inputs were interruptability, redundancy, replaceability and the number of missions affected.

15. SUBJECT TERMS
Mission Dependency Index, Value Focused Thinking, Delphi, Asset Prioritization Index

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